THE

AMERICAN GEOLOGIST

A MONTHLY JOURNAL OF GEOLOGY

AND

ALLIED SCIENCES

VOLUME XXVI

JULY TO DECEMBER, 1900

MINNEAPOLIS, MINN.
THE GEOLOGICAL PUBLISHING COMPANY
c 1900

THE FRANKLIN PRINTING CO., Printers

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SEPTEMBER NUMBER.

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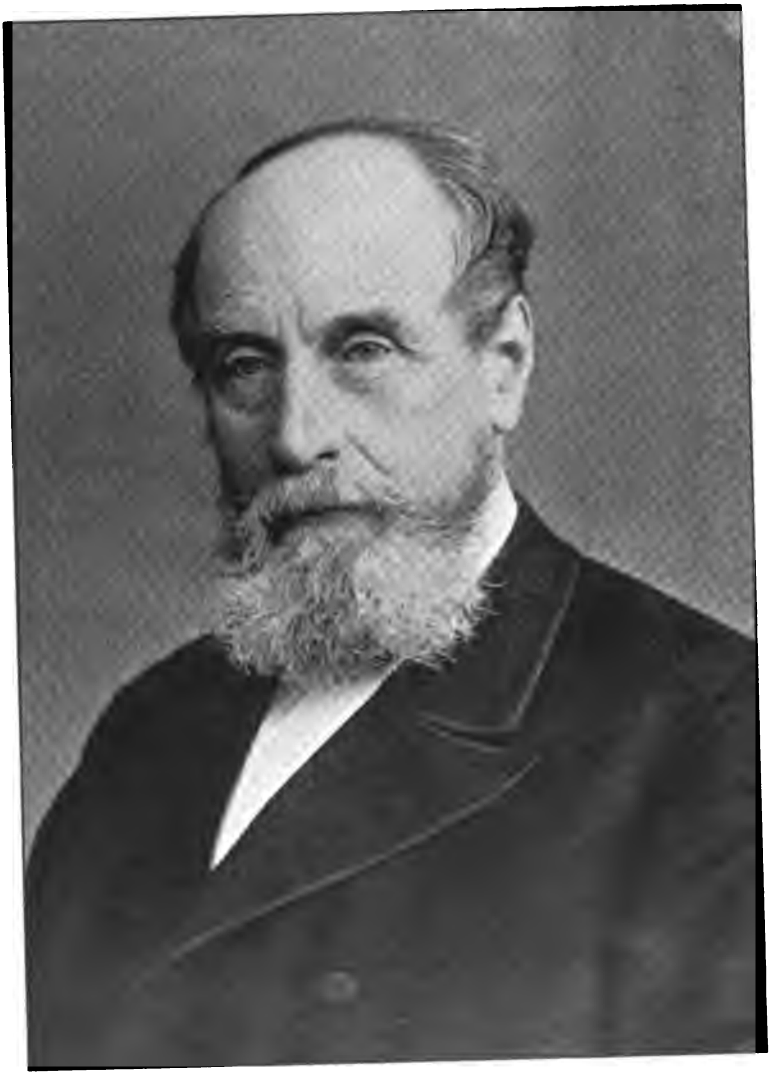
Erratum.

On p. 132, line 26, for Devonian read Ordovician.



SIR JOHN WILLIAM DAWSON.

THE

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VOL. XXVI. JULY, 1900. No. 1

SIR JOHN WILLIAM DAWSON.

A Brief Biographical Sketch.

By HENRY M. AMI, Geological Survey of Canada, Ottawa.

(Portrait).

On Sunday, the 19th day of November, 1899, there passed away to his long rest, one whose name has been inseparably connected with the progress and advancement of geological as well as palæontological research, in the Dominion of Canada. For a few years back Sir William Dawson's health began to fail as advancing years rolled on. The constant strain of a long life of intense activity and incessant labour, at last wore out the chords of life in his person. He died peacefully at his residence, 293 University street, Montreal, just as the first hour of the day of rest dawned, surrounded by his wife and constant companion and a number of his children. Sir William accomplished enough during his life, in the interests of education, science, and religion to satisfy any three hard-working individuals. He leaves behind him such monuments of industry and perseverance as few men do. The Peter Redpath Museum of McGill University alone is a monument which for ages will give food for thought to the coming generations, both to students of the university and to the geologists who seek to unravel the problems of geological science in the different portions of Canada, but more especially those of the maritime provinces, his native land.

Sir William was born in the town of Pictou, Nova Scotia, on October 13, 1820. His grandfather was a Scotch farmer in comfortable circumstances who migrated to Nova Scotia early in the present century, and embarked in business in the town of Pictou. Sir William's father was a well-known book-seller, James Dawson, who was a gentleman of culture and attainments with a taste for study, and for many years supplied the needs of eastern Nova Scotia with the best literature, and published himself several works bearing upon the interest of this old crown colony.

The following is a brief epitomé of his career after leaving Pictou College.

Leaving Pictou he went to Edinburgh University where he remained a winter, and took the degree of master of arts at the age of 22. In 1842 he returned to Canada, and during the summer of that year accompanied Sir Chas. Lyell in his geological exploration of Nova Scotia. In his contributions to the geology of that province, Sir Charles pays many tributes to the ability of his youthful companion as a geologist.

We next find him carrying on a geological survey of the coalfields of Nova Scotia, for which task he had received the provincial appointment, and his report proved of great value. In 1846 he returned to Edinburgh University to carry on special researches and study practical chemistry and kindred subjects, bearing upon the prosecution of geological research.

In 1847 he married Miss Margaret A. Y. Mercer, of Edinburgh, and three years later was appointed superintendent of education for Nova Scotia, and was entrusted with the task of putting a new act into operation. Meanwhile he contributed several papers on economic geology, zoology, and one on forestry.

The establishment of a provincial normal school for Nova Scotia was chiefly due to him, and Sir Edmund Head appointed him a member of a commission to regulate the affairs of Kings' College, now the University of New Brunswick. In 1854, he was elected fellow of the Geological Society of London, and in the following year, appointed principal and professor of natural science of McGill College, Montreal. It was through Sir Edmund Head also, then governor general of Canada, who as governor of Nova Scotia, had watched his

career in that province, that the eminent fitness of Mr. Dawson became known to the governors of McGill College. They were in need of a principal, and had set certain desiderata before them as essential. The new principal must be a layman and besides this, they were determined, that the University should, though Protestant, be entirely undenominational. The principal must nevertheless be a religious man, one who would be a positive influence on the side of godliness. He must be capable and modern, and must of course be young, with his life before him. All these conditionswere found in the young Nova Scotia geologist and in nothing were those who invited him disappointed.

When Sir William assumed the principalship of McGill University, it was a day of small things. The financial condition of that institution at that time made it necessary for him to undertake the duties of several laborious professorships along with those of administration. The revenue then amounted to only a few hundreds of dollars. There were only eight instructing officers, and with the exception of the faculty of medicine, the courses were most unsatisfactory. Under his guidance, however, the institution steadily advanced, and has long since over grown the effects of the depressing influences under which it labored when he was appointed. One of the great drawbacks to the success of the university was the lack of sufficient schools to prepare pupils for matriculation. With the co-operation of Sir Edmund Head, and of the superintendent of public instruction for the province of Quebec, in 1875 he secured the establishment of a normal school for Montreal, affiliated to McGill University, for the training of Protestant school teachers.

He was principal of McGill normal school for a period of thirteen years, in addition to his university duties. In 1858 he succeeded in establishing a school of civil engineering and surveying, which, however, after a severe struggle, succumbed at the end of five years to unfriendly legislation. Eight years later, however, he resuscitated this faculty of the university and placed it on a firm basis, so that to-day the faculty of applied science in McGill University is recognized as one of the best equipped and most thorough institutions, an object of pride not only of Montreal, but of the whole of the Dominion.

For eight years Sir William was a member of the board of Protestant commissioners of schools for the province of Quebec. He was also a member of the council of public instruction for the province of Quebec. In 1862 he was elected fellow of the Royal Society of England, and, in 1865 lectured before the British Association for the Advancement of Science in Birmingham. Five years later, 1870, he also lectured before the Royal Institute and Geological Society of London. In 1875 he was foremost in advocating the union of the several bodies forming the Presbyterian church in Canada, which union was effected in that year.

In 1881 he received the Lyell medal from the Geological Society of London for his important discoveries in science, and Her Majesty Queen Victoria created him a companion of the order of St. Michael and St. George, (C. M. G.), for his brilliant career in the same. In 1882 he was selected by the marquis of Lorne to be the first president of the Royal Society of Canada, which society has since flourished under both vice-regal and parliamentary patronage. In 1883 he was knighted by Her Most Gracious Majesty, in due recognition of his scientific work and his successful promotion of higher education.

With reference to the founding of the Royal Society of Canada, in a terse manner Sir William Dawson thus points out one of the objects for which this society was formed. "I would place here first," he says, in speaking of the ends which the society may seek to attain and the means of their attainment. "the establishment of a bond of union between the scattered workers, now widely separated in different parts of the Dominion. Our men of science are so few, and our country so extensive, that it is difficult to find in any one place or within reasonable distance of each other, half a dozen active workers in science. There is thus great lack of sympathy and stimulus and of the discussion and interchange of ideas, which tend so much to correct as well as to encourage. The lonely worker finds his energies flag, and is drawn away by the pressure of more popular pursuits, while his notions become one-sided and inaccurate through want of friendly conflict with men of like powers and pursuits. Even if this society can meet but once a year, something may be done to remedy the evils

of isolation. * * * Again means are lacking for the adequate publication of results. Transactions are published by some of the local societies, but the resources at the disposal of these bodies are altogether inadequate, and for anything extensive or costly, we have to seek means of publication abroad; but this can be secured only under special circumstances; and while the public results of Canadian science become so widely scattered as to be accessible with difficulty, much that would be of scientific value fails of adequate publication, more especially in the matter of illustrations. * * * Should this society have sufficient means placed at its disposal, to publish transactions equal in—I shall not say to those of the Royal Society of London—or the Smithsonian Institution at Washington—but to those of such bodies as the Philadelphia Academy or the Boston Society of Natural History, an incalculable stimulus would be given to science in Canada, by promoting research, by securing to this country the credit of the work done in it, by collecting the information now widely scattered, and by enabling scientific men abroad to learn what is being done here."

In the same year he was elected president of the American Association for the Advancement of Science, which body met in the city of Montreal, under the ægis of McGill University. It was in 1882 that the Peter Redpath museum of McGill University was inaugurated. The collections which adorn the main floors and galleries of this munificent gift of the man whose name it bears, were for the most part the result of personal labours and endeavours on the part of Sir William himself. By dint of constant collecting wherever he went and a regular system of exchange by means of which he not only enriched the cabinets at McGill, but also made known Canada's geological resources to the world of science abroad, he obtained a vast quantity of material which is now exhibited in the Peter Redpath Museum.

In 1884 he was instrumental in bringing the British Association for the Advancement of Science to Canada, and two years later, he received the high distinction of president of that association. In 1893 he was elected fellow of the Geological Society of America, and in the same year he retired from the principalship of McGill University and was appointed emeritus

principal and professor, also a governor's fellow and honorary curator of the Peter Redpath Museum. In 1895 the rare distinction of honorary fellowship of the Royal Society of England was conferred upon him. Sir William Dawson was also a corresponding fellow of the Geological Society of Edinburgh, a corresponding member of the Victoria Institute or Philosophical Society of Great Britain, a corresponding member of the Geological Society of France, of the Nova Scotian Institute of Science, Halifax, and he was also many years president of the Natural History Society of Montreal, which society he did much to bring to its present status in the world of science and research, and up to the past year was Honorary President of the same.

He was also member of many active bodies engaged in scientific pursuits throughout the world. He was also in touch with the various graduate societies of McGill University throughout the length and breadth of this continent and was particularly happy when he found himself in the midst of a body of old graduates of McGill to whom he could speak of the past, present and future of the University for which he had laboured so faithfully and so long with such remarkable success.

In 1884 Sir William received the degree of LL. D. from the University of Edinburgh.

Sir William was highly systematic in all the work he undertook and though his was a busy life, he was ever calm and collected with any amount of reserve force and energy at his back. He met even the humblest child with courtly grace, generous spirit and dignity, commanding the respect and admiration of all those with whom he came into contact. He was a true friend of the student, he had the wonderful faculty of remembering faces and names so that even a student in the junior years he would recognize and salute first, wherever they met.

As an educationist, Sir William takes rank with the few who built up our educational institutions in Canada, and gave them a high character. From the early years of his career in Nova Scotia as superintendent of education until 1894 when he resigned the principalship of McGill University he never ceased to work in the interests and for the promotion of learn-

ing in the highest sense of the term. He sought in an effective and practical manner to give to the various classes of students under him the most advanced results of science, and research. Science education abroad occupied his attention and from the result of his observations and his knowledge of the needs and importance of practical science education, he applied the best methods of teaching in the university under his care. A careful study of methods of work, and teaching in the Royal School of Mines, the department of science and arts, London University, the Royal Institution, Owens College, Manchester, science teaching in Cambridge and Oxford, and the movement in Edinburgh, in the Sheffield Scientific school, together with science teaching in the technical universities of Germany and Switzerland formed a subject of an important paper from his pen. The want of science teaching in Canada and what was being done at Montreal in 1870 towards establishing the faculty of applied science at McGill, and the lines in which practical science training should fall, were carefully delineated.

Sir William was particularly happy when, out in the field with a class of students or with the members of the Natural History Society of Montreal on their annual excursions, he was engaged in examining the geological phenomena of the various localities visited, and instilling into his hearers the zeal of his enthusiasm, with what vigor and dexterity he wielded the hammer. His keen, penetrating eye and a sharp lookout for any rare species or new form of fossil organisms was very evident on all such occasions. He did much to foster and encourage collecting specimens in all branches of natural history. He was eminently practical in all his teaching, and as may be seen from the large accumulation of material now displayed in the cabinets of the Peter Redpath museum, he enlisted the co-operation of the students of the university both during and after their college career, and thus materially assisted in building up that monument of his industry.

* * * *

Sir William was the first librarian of McGill University, and he began a catalogue of the few books which constituted the library at that time—1856—and from this small beginning sought to bring together all the available volumes bearing on science and literature for the benefit of the students under his

charge. During a recent visit to the Peter Redpath library of McGill University, the writer was shown the first series of volumes, actually the first book, to be catalogued by Sir William, under Class A, Number 1, of the Library of McGill College, Montreal. Mr. C. A. H. Gould, B. A., present librarian of the university pointed out that by a remarkable coincidence. "The Annual Register," Vol 1 of which was the first book catalogued by Sir William, was also the first to be catalogued in the new Peter Redpath library, when amongst the thousands of volumes donated by Peter Redpath, Esq., to the university. "The Annual Register" was again the first series to be catalogued.

* * * *

As a Bible student and expositor, Sir William stood high. He ploughed deep in the books of holy writ, and subjected those writings to the same keen, critical sense to which he referred various other problems in the scientific world, and brought out many hidden truths from the word of God, which had been hitherto obscure. "Egypt and the Holy Land, their geology and natural resources," "Eden Lost and Won," "Archaia," "The Mosaic Cosmogony," "Modern Science in Bible Lands," "The Origin of the World, According to Revelation and Science," form part of a series of writings of an apologetic character, which in his day, Sir William Dawson deemed necessary to combat certain views that were thrust upon the more or less observant and thinking world, regarding the origin of man as well as of other species living upon this planet. These have no doubt played a conspicuous part in establishing the present more or less evident equilibrium which exists in the thinking world regarding the relations which exist between our beliefs in religion as well as in science. They are two distinct spheres, and our earnest endeavours ought to be directed towards the perfection of our knowledge in one direction as well as the other, in order to satisfy these two sides at least of our nature.

* * * *

Simplicity and humility were the leading characteristics of Sir William Dawson's religious life. He was a member in full communion of Stanley Street Presbyterian church, and was appointed commissioner to the General Assembly of the

Presbyterian church in Canada on several occasions. He loved to worship with this quiet, retired congregation, where psalms and hymns were sung without instrumental accompaniment. For many years, he led in the Sunday School, and subsequently conducted a most successful class for teachers, which was composed of the teachers of the various Protestant denominations of Montreal. In every movement that had for an object the moral uplifting and bettering of the conditions of life in the Canadian metropolis his name was invariably connected, and in season and out of season, he never lost an opportunity of giving public expression to his keen sense of right and justice. His was a well-spent life, unselfish in all its aims and purposes, unsparing in his efforts to advance the interests of his fellow citizens and of humanity in general, exercising withal, a power and influence for the moral good and welfare of all in a high degree. In the language of Socrates, regarding a well-spent life, we can truly say of his,

"Καλον γαρ το αθλον, και η ελπις μεγαλη."

"For noble is the prize and the hope is great."

As a writer, who sought to present in popular form the results of geological science to a larger audience than greeted him on the college benches, he was eminently successful. Among the most conspicuous of his popular writings in which the relations which exist between science and revelation were usually made a portion of his theme, the following may be mentioned: "The Story of the Earth and Man," "Facts and Fancies in Modern Science," Fossil Men and their Modern Representatives," "Modern Ideas of Evolution," "The Meeting Place of Geology and History."

The many editions through which these various writings passed and the ready sale of his writings on both sides of the Atlantic, testified to their popularity. Throughout the English speaking world his name was a household word, and a letter of introduction was a passport in every country in Europe.

Here is an example of Sir William's writing showing his intense love for the 'right' and the 'truth', coupled with a hatred of the 'wrong' and injustice which needs supernal power to remedy.

"Surely man is the spoiled child of the Creator, allowed

by an over-indulgent father to destroy the valuable things which he cannot appreciate, or which his own misconduct has rendered it necessary for him to apply to purposes not intended by the Maker either of man or of the lower things which he misuses. Surely it is the same indulgent Father, who causes His sun to shine on the evil and the good, and who provides a Saviour for the unworthy and the disobedient, though He is also a rewarder of those who diligently seek Him, and will not prevent the penalties of law whether physical or moral from falling on the reckless and impenitent. There is surely a latent gospel in nature, which has always been proclaimed in it, though often to heedless ears, and which required the infinite knowledge and love of Jesus to interpret it clearly to us. No doubt this gospel like that of Christianity itself, is turned into gall and bitterness by modern pessimistic advocates of the mere struggle for existence; but to rightly constituted minds, Christ's interpretation is better, as it is also more happy and hopeful."

For a period of twenty-two years I was acquainted with Sir William Dawson. He had just completed twenty-two years at McGill, when I entered that University. Who could forget those precious evenings and hours spent in Sir William and Lady Dawson's company, both at home in the University hall, in the museum or geological labratory? Those evenings especially were of a nature calculated to elevate and inspire. With microscopes, specimens and books, with illustrations of natural history objects, and a thousand and one objects of beauty and interest in nature he sought to plant thoughts in the minds of his disciples, and interest them, or assist in developing their faculties of observation and comparison—those two great media of exact knowledge of science.

In the classroom as a teacher, Sir William had few equals. From the time he entered the university and punctually to the minute, he captivated the attention of his hearers by his wonderful flow of beautiful, descriptive language, coupled with the particularly happy faculty of graphically and accurately representing upon the blackboard in colored chalk, the various structures and illustrations in natural history, whether in botany, geology, zoology, or palæontology. It is currently reported that there are not less than ten persons now employed

in the university, doing the work which fell to the lot of Sir William Dawson, during his tenure of office in the university from 1855-1899.

Besides his duties as principal and vice-chancellor of the university, member of the corporation, as well as chairman of the faculty of arts, he filled the chairs of chemistry, botany, zoology and geology, including mineralogy, ethnology and palæontology for many years, including both the ordinary course of lectures and the honour or advanced courses.

One of Sir William's strong points was the conciliatory nature of his arguments. He was always the broad-minded and many-sided man. He could see a thing in its all around aspect, and was ever calm and collected in what could scarcely even be called troublesome times.

Like all strong-minded men, Sir William had his foes, but withal, he always manifested a dignity of spirit, and unswerving love of truth, together with a strong tendency not to break away too suddenly from the well-known and rather conservative view of things; he went on in the even tenor of his way, usually carrying his point and leading his very opponents step by step to see the situation from his standpoint.

With the interest of the university at heart, imbued with a powerful and ever increasing faith in the constitution of the university of which he held the helm, with a far-seeing eye, he went on, determined to carry his points however far-reaching they might be.

Life with Sir William was a serious thing. It had with him an earnestness and an increasing, ever active interest. He was both orderly and systematic. His own library, work-room and museum were models of order and neatness, and every minute of his life seems to have been occupied. When we consider the task which he accomplished—the University which he leaves behind him—the monuments which on every side on the college grounds are fruits of his skill and labour, tact and a hopeful nature, we appreciate the persuasive power which inspired confidence and won for him and the university scores of friends. All the students under him loved him. The wealthy merchants of Montreal, who came within the sphere of his influence (and he made it his business to instruct and inspire many of them in the ways of munificent donations to the Uni-

versity), recognized in him one in whom they could with all true confidence rely for judgement on the question of higher and practical education.

To those of us who have had the pleasure and privilege to listen to his marvelous flow of language, his lucid descriptions, as well as to those of us who have studied under him and who are now following up the science which he so dearly loved, and which he so generously imparted, with an inspiration and a zeal which but few masters possess, it may be said that we have caught something of the fire and earnestness of his life and spirit. When we see the results achieved during this useful life, to those who ask, we say, "Si quaeris monumentum, circumspice."

* * * *

His career as a scientist brought him in contact with all the leading scientists of the day, especially in the branches of botany, geology and palæontology. Between Sir Wm. Logan and Sir Wm. Dawson a strong friendship was formed. These two kindred spirits joined in advancing the interests of geological inquiry in Canada, and by their united writings, as well as by those of the late Elkanah Billings,—the palæontologist of the Geological Survey from 1856-1876—helped to make the name of Canada well-known in Europe, but more especially in the great centres of learning in London, Cambridge, Oxford, Edinburgh, Manchester and Glasgow.

With Sir Richard Owen he did much to make known the early batrachian which inhabited our planet, and as mentioned before, he accompanied Sir Chas. Lyell on two occasions when the latter visited Canada.

With Jones, the Woodwards and Hinds, with Marsh, Claypole and Cope, with Lesguereur, H. S. Williams and Walcott, with all the members of the Geological Survey staffs of Canada, the United States and Britain, was he well acquainted. In France and in other portions of the Continent, his was a household name, and a letter of introduction or card from him carried in the hands of any of his former pupils, or friends, would be a passport in all scientific circles.

In 1893 a severe attack of pneumonia compelled Sir William Dawson to seek a warmer clime and he spent a portion of that year along the Florida coast. From this on he never

regained his accustomed strength, and one day, while he was busily engaged in the Peter Redpath museum, he suddenly fell, a victim of a slight attack of apoplexy. Nevertheless, he gradually recovered, and whilst his bodily vigour was sensibly diminishing, his mental grasp of the various problems to be solved in Canadian geology was very marked. As late as July, 1899, in the course of a conversation that the writer had with Sir William, regarding difficult points in Nova Scotian geology, as well as the result of recent investigations carried on by a committee of the British Association for the Advancement of Science, on the pleistocene fauna and flora of Canada (of which he was chairman), he evinced remarkable strength of mind and clearness of judgment. This interview was followed by a long letter, in which Sir William pointed out in a masterly manner the various phases of the question at issue, showing the full comprehension of the situation his mind still possessed. For the best part of two years Sir William was practically an invalid, and had to be carried or lifted from place to place, in all of which he evinced a calm resignation and faithful hope, which accompanied him and seemed to add even joy to those otherwise sad moments, until the final crisis and end came. The gold of Ophir and problems relating to it from recent discoveries made in South Africa, were occupying his attention only ten days previous to his demise.

On March 19, 1847, Sir William, then Dr. Dawson, was united in marriage with Miss Margaret A. Y. Mercer, Edinburgh, daughter of D. Mercer, Esq., of Edinburgh. There are five surviving children, the eldest of whom, Dr. George M. Dawson, C. M. G., F. R. S., &c., has followed the footsteps of his father, and given his life entirely to geological pursuits. He is now director of the Geological Survey of Canada, and is a Fellow or member of all the leading geological societies of North America and Europe. Mr. William Bell Dawson, a civil engineer, has charge of the tidal surveys of Canada in connection with the department of marine at Ottawa. Dr. Rankin Dawson, the youngest of the three sons, is now practicing medicine in London, England. The two daughters are Mrs. J. B. Harrington, wife of the professor of chemistry at McGill University, and Mrs. Pope T. Atkin of Rock Ferry, near Birkenhead, England. Lady Dawson, who survives her

husband and who was his constant companion for upwards of fifty years, is entitled to great credit for the conspicuous part she played in seconding Sir William's efforts to promote the interests of the university and of exercising that wholesome influence of a true Christian home, which ever characterized their hospitable abode, to which many of us look back with pleasure.

In March, 1897, the golden wedding of Sir William and Lady Dawson was celebrated at Montreal, on which occasion they were made the recipients of numerous addresses of congratulation and messages from the graduates of the university and friends in general the world over, accompanied by souvenirs of the interesting event, which took place at their home, 293 University street, Montreal. On that occasion, there was a reunion of all the members and friends of Sir William's household, so that in his declining years, but two years previous to his departure from this life, he had the pleasure of witnessing an event which it is permitted only to a few in this world to celebrate.

I learn from good authority that Sir William Dawson has left behind him a large amount of material, notes, papers, correspondence, and documents relative to the university, with a view of preparing a history of that institution of learning. It is to be hoped that before long these will fall into the hands of a competent person, who will prepare this work which the late lamented principal no doubt expected to complete. It would add one more tribute to the memory of him who did so much to build up that centre of excellent, practical education.

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POSSIBLE NEW COAL-PLANTS IN COAL. Part II.

By W. S. GRESLEY, F. G. S., F. G. S. A., Erie, Pa.

(Plates II, III, IV, V.)

The editor of this magazine having expressed a wish that the results of my continued research in fossil plants, be published (see Vol. XXIV, p. 199, Oct. 1899), in order to show (1) progress made in determining the organized plant constitution of coal, and (2) that possibly there may be something new herein, I gladly avail myself of this opportunity.

In presenting further installments in this increasingly interesting line of investigation, I desire to say, first, that my intention has been to illustrate only such objects and anatomical structures as I have detected in coal which have not, so far as I have been able to ascertain, been already figured and described. Secondly, I make no pretension to be a botanist, but, in making the drawings of the specimens, have carefully avoided the imaginative and the fanciful. I have endeavored to see what the specimens had to reveal, and then to draw, to scale as far as possible, what I saw or believed I saw in them and rejecting that which I had no reason to suppose would add value to the matter. Thirdly: By way of increasing interest in these fossils, where advisable, notes or suggestive remarks have been made, following the descriptions of the figures in the plates.

Should a further interest be evinced in this connection, the author announces that he possesses what he believes to be a very interesting addition to our knowledge of the Carboniferous coal-plant inflorescence, fructifications and allied forms and fragments, some of which may prove to be new to science.

Reference to Plate. II.

Fig. 1. Vertical section of a fragment of anthracite showing portions of two layers of nearly black and compact coaly material, apparently consisting of little black elongated or distorted rings embedded in a dark gray matrix, and filled with a very similar material. The lower edge of the upper layer and the upper one of the lower layer consist of black material not unlike that constituting the ring-like bodies. That these black and gray bodies are not really rings nor oolitic in form, but are tubular, becomes evident when the specimen of coal is examined on its side face or longitudinal or oblique fractures.

Fig. 2. Transverse section, magnified, of the tubular structures or elements sketched in figure 1; also showing the character of the cellular tube filling, that of the intertubular material, and of the more dense and blacker edge of the fossil—the lower portion of the figure, which is observed to be rent or ruptured near the right-hand corner.

Fig. 3. Longitudinal section through a. b. of figure 1, revealing the character of the various elementary structures of which the specimen is composed, c being a tube and e. p. ? the epidermis, Within the tubes, black rod-like bodies may sometimes be seen (see figures 2 and 3). These, when present are either well within the tube's core or are near to the tube-wall.

Fig. 4. Transverse section of a portion of the cells enclosed in the tubes. They are gray in color.

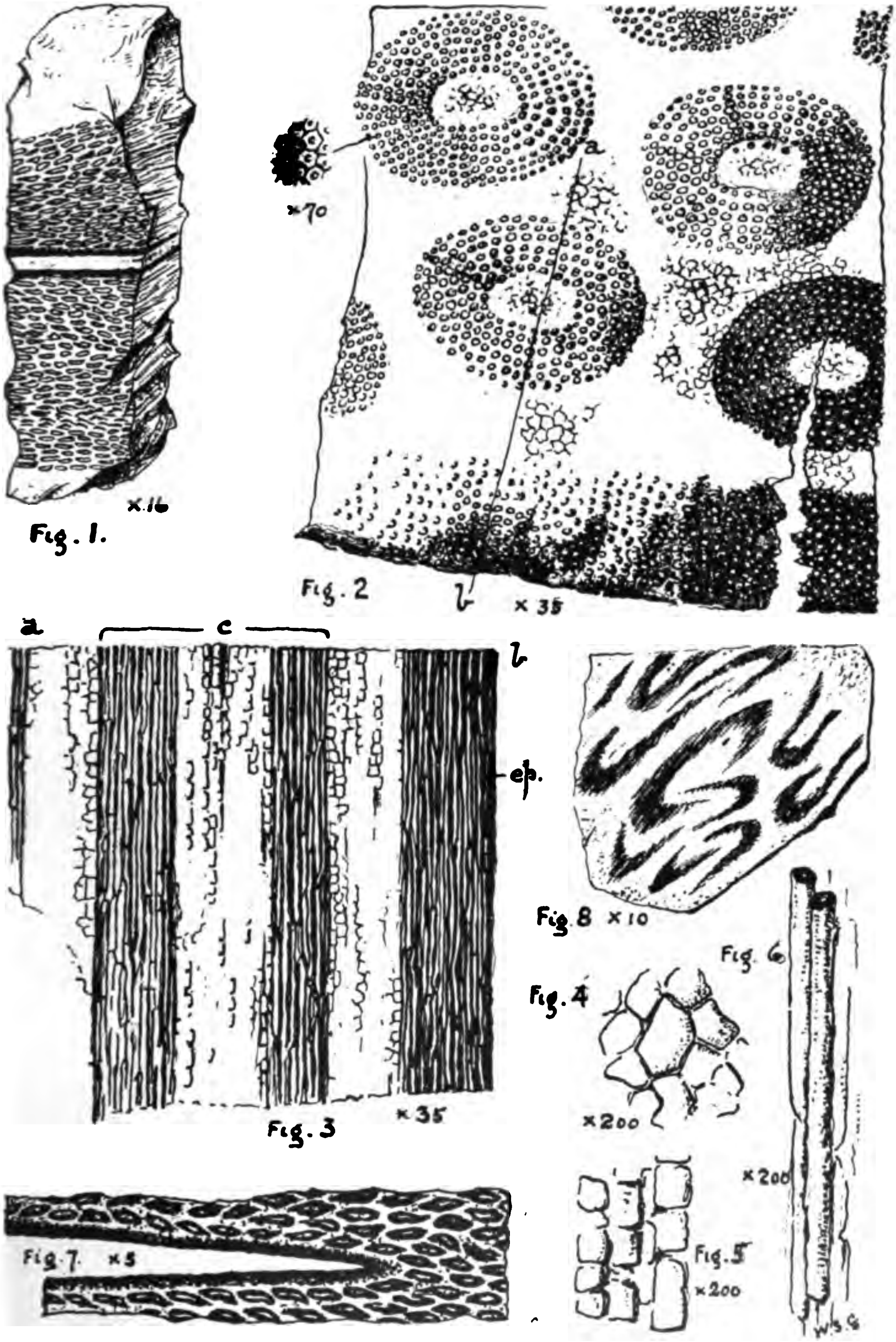
Fig. 5. Longitudinal section of a portion of the cellular tissue of the intertubular material; also gray in various shades.

Fig. 6. Longitudinal section of a portion of the very thick-walled fibrous material constituting the tubes, and apparently the ? epidermal layer as well. The cores or centres are of a gray substance.

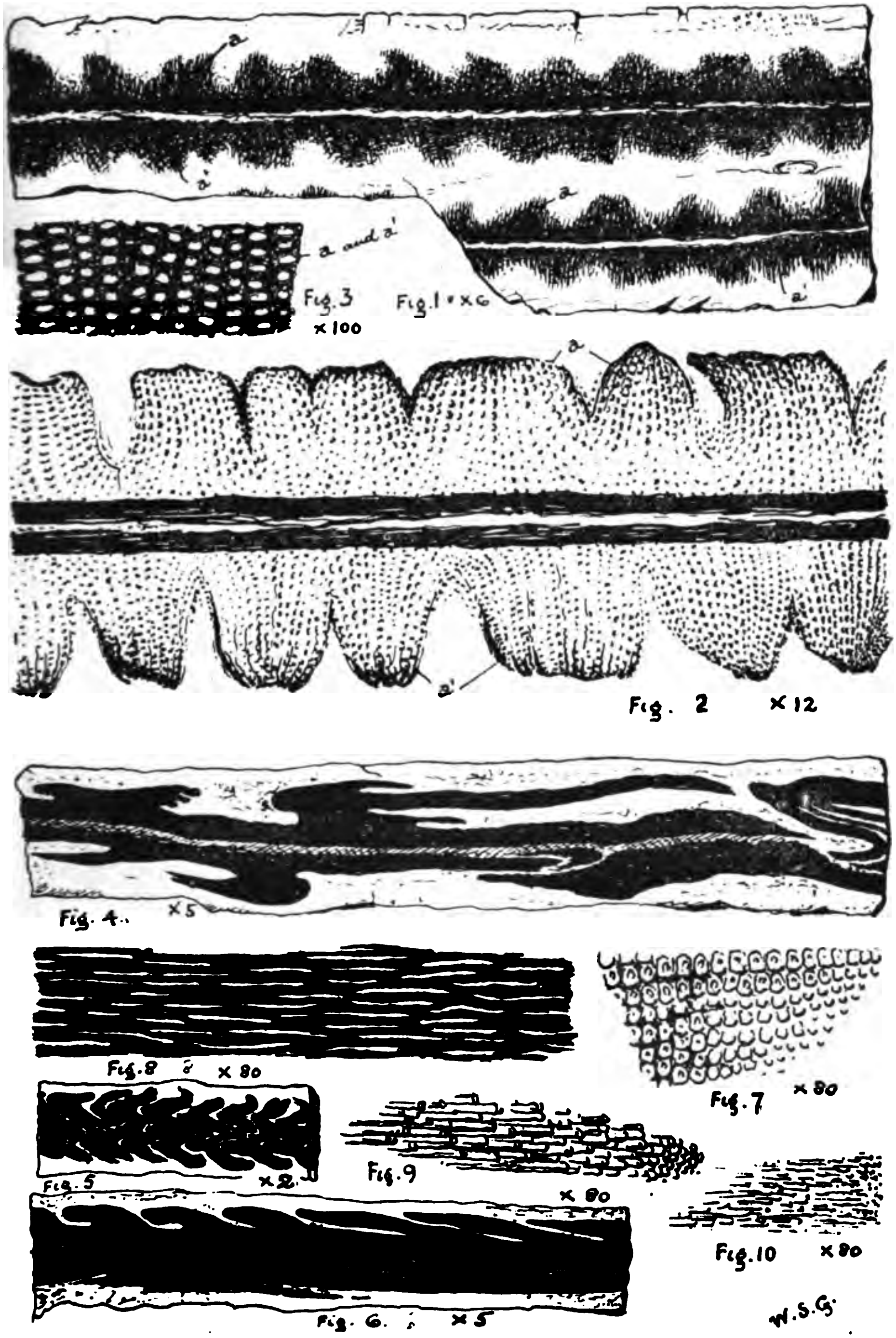
Fig. 7. Rather oblique section of part of a layer or mass of this species, exhibiting the ? epidermis in a shape suggestive of a deeply grooved stem or ? bifurcation of the plant.

Fig. 8. Oblique section of a part of a mass of ruptured and disturbed tubes—a feature not uncommon with this form in the coal.

Notes on the foregoing: This fossil plant occurs in horizontal layers or plates of unknown shape and area; the largest individual specimen, and that merely a fragment, showed about twenty square inches in area. In thickness or vertical hight in the coal, it runs from two or three tubes to at least thirty. The individual layers of it sometimes occur closely stratified, one above another; fig. 1 shows two layers. In vertical diameter the tubes seem to average about 1-150 of an inch, and say 1-75 of an inch horizontally. The lengths of the tubes have not been determined, but some of them measure at least one inch. The thickness of the core of a tube is about one-fourth of the tube's diameter. All the elements seem to lie parallel to each other, and notwithstanding this fossil is quite common in anthracite yet no suggestion of any cross-grain or of medullary rays has been detected. Some specimens show the tubes twice as large as do others, and there appears to be a gradation in size as one would naturally expect to find. These tubes, etc., appear in the coal much as do corals in polished black marble, but to the naked eye they are rarely visible. It is in the



STRUCTURES IN COAL.



STRUCTURES IN COAL.

contrast in color, between blacks and grays, that their presence is quickly revealed to the investigator. This species is associated with many other kinds of vegetation, among which are those treated in the Oct. 1899 number of this magazine, and intended to be illustrated in future. Appearances suggest a monocotyledonous stem, devoid of outward curving bundles; observed also in the "Pittsburg" coal bed, the No. II seam of Illinois, and in the coal bed at Whatcheer, in Iowa.

Plate III.

Fig. 1. Nearly vertical section of parts of two similar species of what is possibly a coal-plant new to science. These two irregular blackish layers constitute, as ordinarily observed and to the naked eye, a pair of pitch-coal lamina in ordinary coal. On closer inspection, however, each of these layers or zones is composed of five more or less horizontal streaks or leaves of irregular form, namely a gray central zone, merging here and there into a dense black zone above and below it; and on each side of this again, i, e., constituting the upper and lower parts of the specimens, appears a grayish black, wavy, or tooth-shaped zone, marked a and a′ in the figures 1, 2, and 3. It is only in the zones a and a′ that organized structures have been detected.

Fig. 2. Approximately vertical section of part of one of the layers in figure 1, enlarged in order to give an idea of the cellular structure observed in the zones a and a′, each of which appears to be practically a counterpart of the other. The scale to which this drawing has been made is, however, much too small to show more than about one-tenth of the number of the rows of cells in each split tooth or lobe of the layers, and of the number of separate cells in each row.

Fig. 3. Gives a rather better idea of the aspect of the cells whose arrangement and grouping is indicated by figure 2. The cells appear as little gray dots in rows, and the cell-walls (black) seem to be quite thick. It should be noted that while no bedding-plane or parting exists along the base of the layers a and a′, the cellular structure begins in an even, definite, and clear manner along or upon the dense black strucureless zones as shown in figure 2.

Observations regarding the specimens (figures 1, 2 and 3, plate III.) No edges or terminals, looked for in a horizontal direction in the specimen of coal in which this form occurs, have been detected. The specimen of coal is about two inches in thickness, i. e., it contains about that thickness of the particular bench or division of the seam it was taken from—the "Ten-Yard" or "Thick Coal," of South Staffordshire, England, and in this two inches or so are four or five individual (?)

specimens of this plant-fragment; some being less pronounced than others. Whichever way the specimens are broken transversely, the same, or apparently the same, cellular structures and tooth-shaped exteriors are observed, and no other kind of tissue has been recognized in these zones a a'. The ground mass of the coal—the matrix in which those particular fossils are embedded, seems to consist chiefly of small detrital plant remains in the shape of black streaks and patches, with macrospores here and there, in a dark gray granular material which seems to be impregnated by (?) amberite, or clear, solidified ? petroleum.

As to the true character or determination of this form; at first sight it might be taken for the flattened or compressed woody wedgs (exylem) of the calamite, the sigillaria, the stigmaria or some other coal-measure plant: but to the author, there seem to be several reasons why this cannot be so, namely: The specimens fail to reveal any suggestion of the thin edges or apices of the woody wedges, in fact the very regular structures existing along such a horizon is the reverse of what such flattened wedges would show. Secondly. Instead of gaps or openings in the outer margins of the layers a a' which give to the specimens the tooth-shaped aspect, these could not have formed, there would have been a crowding instead of a stretching of the material in this position. Thirdly. No medullary rays or other cross-graining is present, and the tout ensemble seems to suggest something quite different from the genera named in this connection. If these are or could represent woody wedges, then the dense black central material would be fossilized pith, and pith, we believe, did not become mineralized into pitch-coal layers, but rather went to form much of the dull gray material of coal. Whatever this fossil really was, its mode of occurrence in the coal as well as its individual peculiarities, here pointed out, seem to indicate that it is practically in place of growth, apparently reduced in bulk vertically as regards the central zones, but not materially compressed as to the outer zone a and a'. So far as has been determined it is of the unicellular order or group.

In a coal-bed in Michigan, the author has detected a specimen of somewhat similar facies.

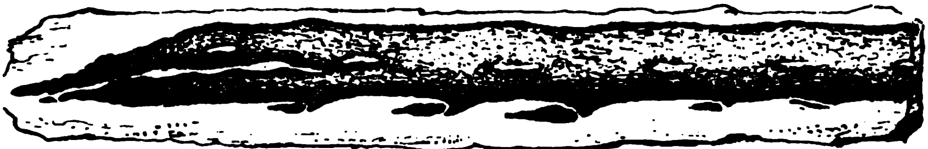


Fig. 1 ×6

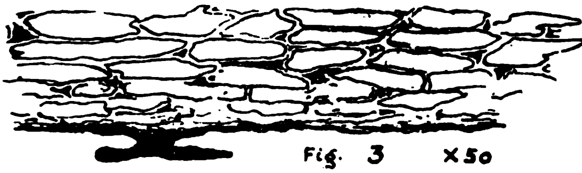


Fig. 3 ×50

Fig. 2 ×20

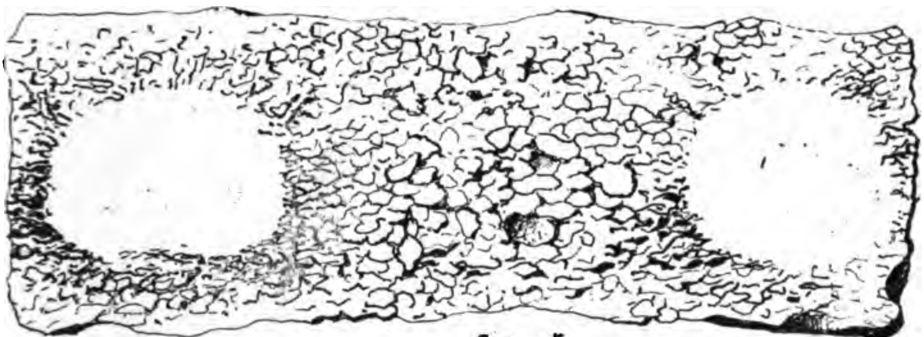


Fig. 5 ×25

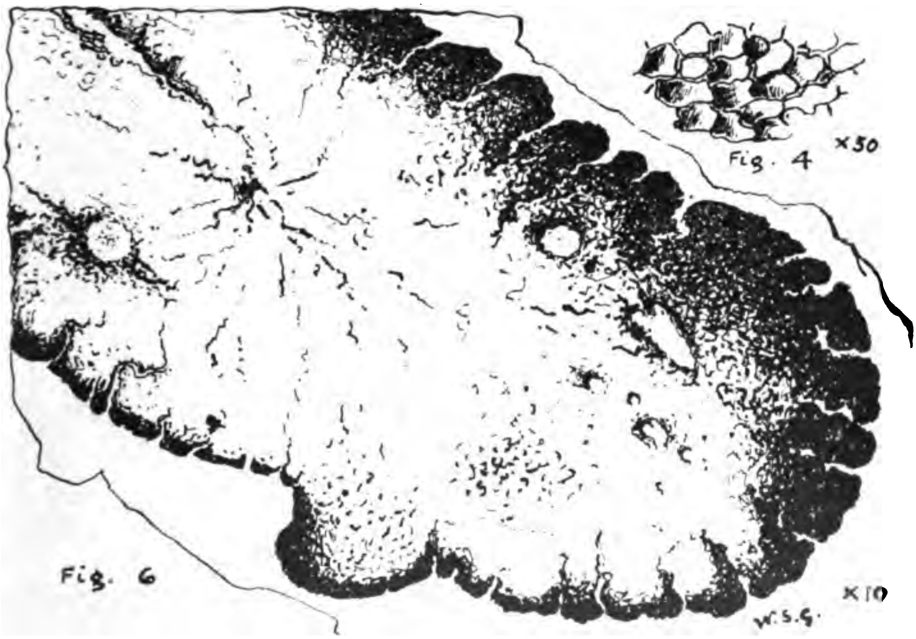


Fig. 4 ×50

Fig. 6 ×10

W.S.G.

STRUCTURES IN COAL.

Figs. 4, 5, and 6. Are approximately vertical sections, about at right angles to the planes of the laminæ of the coal, of fragments of different specimens of what seem to represent the same genus or species of a hitherto ? undescribed coal-forming plant: and one that is not at all uncommon in Pennsylvania anthracite. These forms constitute some of the brilliant black laminations pervading, or having a wandering-about aspect in the duller and grayish groundmass of this coal. Though for the most part consisting of very dense black and apparently structureless material, yet, when carefully split as nearly parallel with the bedding-planes as possible and then viewed under favorable illumination, suitable specimens will reveal a beautiful cellular to fibro-cellular organization.

Fig. 7. The aspect of the cellular structures composing the exterior portions and lobe-like expansions of the specimens.

Fig. 8. Longitudinal section of the cellular structure shown in figure 7.

Fig. 9. Oblique view of the cellular material composing the grayer central portion of the specimen, figure 4. These vessels or fibres are of smaller diameter than those of the more marginal parts of the fossil.

Fig. 10. Oblique section of the structural material of the fossil as observed part way between the structure figures 7 and 8 and that in figure 9.

Notes on the above. These forms, whatever they may be, are much broader than they are thick. Their leaf-like and lobe-like, irregular surface (as proved by very numerous specimens exhibiting a great variety of differences in form and shape, according to form and direction of fractures made in order to examine the specimens), are decidedly indicative of a meandering form of plant, and possibly one possessing a unicellular structure, since, all the organized tissues seen lie parallel to each other and seem to grade one into another. To the author's mind there is something so natural about the aspect of the leafy externals of these forms, curving, curling and meandering about in the gray matrix of the coal as they seem to have been doing when converted into their original coaly state, (not anthracite, of course), as to suggest that the plant is in place of growth and that it grew horizontally.

Plate IV.

Fig. 1. Vertical section of a fragment of some plant, occurring in the form of a blackish lamina in the paler matrix of Pennsylvania anthracite. This specimen is forked or shows two lobes along its left

margin. A row of elongated spots, pale gray in color, appear in an orderly arrangement along near the middle of the fossil. The upper (as figured) margin of the specimen is black compact anthracite; the central area is gray; and the lower side (as figured) nearly dense and black as is the upper edge, but much thicker. Along the lower exterior (as drawn in the figure) are ridges or horn-like protuberances, in the cavities of which, small, elongated, black areas appear. The inner borders of the forked end of the thing are of compact, black, coaly material grading into gray towards the middle of the lobes.

Fig. 2. An enlarged view of one of the bud-like excrescences seen in figure 1.

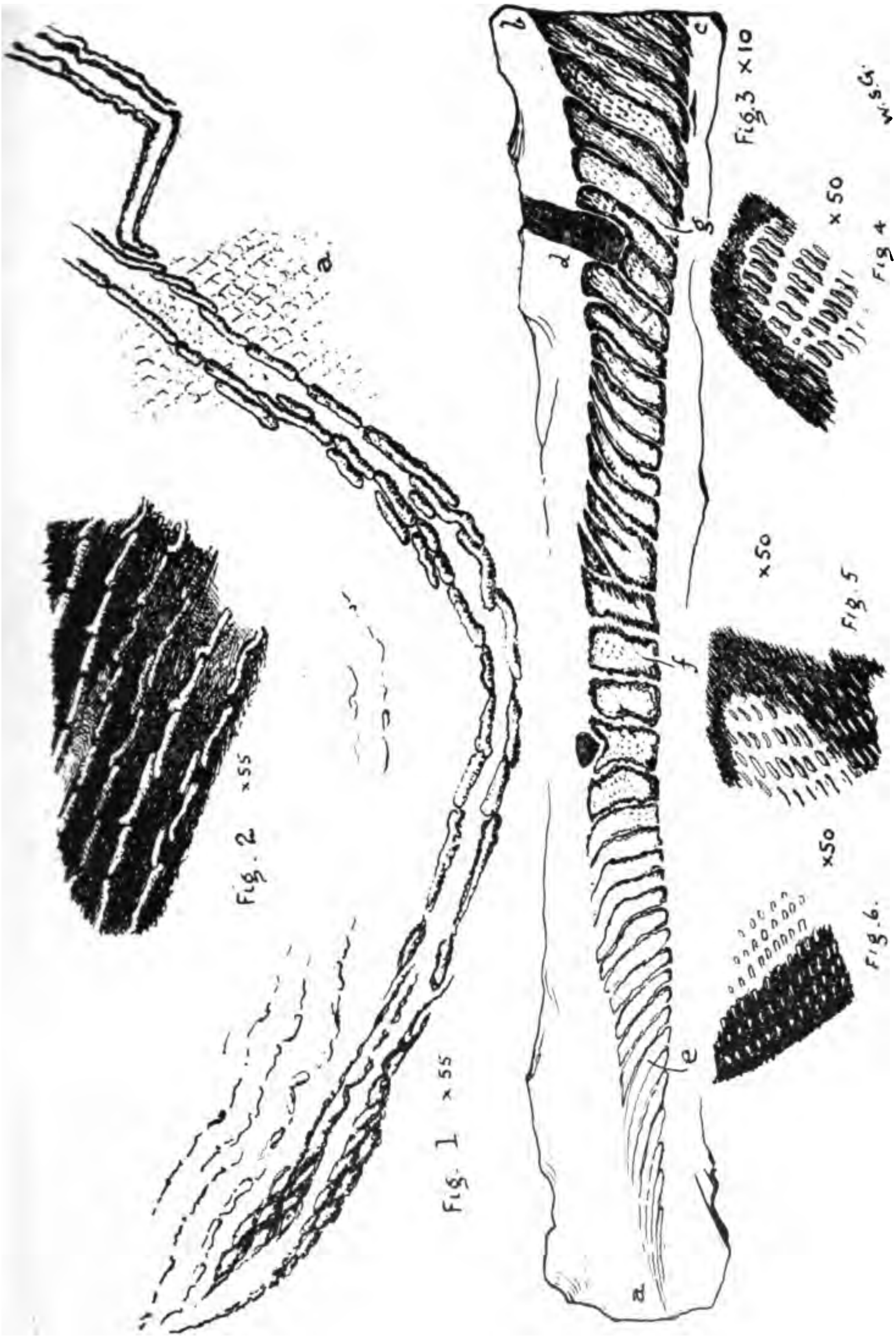
Fig. 3. Longitudinal section showing the character of the organized structure of the whole of this fossil or plant. The cells are of a darkish gray color, and grow narrower as the margin of the plant is approached, finally becoming lost to view in the black and dense exterior. The specimen appears to be about 135 cells in thickness in the middle.

Fig. 4. Transverse section of the cells of figure 3. Some of them seem to be only partially filled with ? carbon, etc., i. e. cavities occur in some of the cells, giving to the substance a slightly porous aspect.

Fig. 5. Longitudinal section, in plan, through two of the pale gray "spots" seen in figure 1. The cell structure of the specimen is most strongly developed furthest from the spots, while the margins of them are of cells crowded and quite small. The spots themselves show no organized structure, and their composition is dull and fine-grained.

Fig. 6. Longitudinal section, in plan, of one end of a specimen of the same species showing: a, characteristic lobed or rugged margins composed of very compact black material, in which the cellular structure is but just visible; b, several pale "spots;" and c, a sort of nucleus or central point from which radiate in all directions more or less distinct wavy lines passing through the organized structure, which, all over the specimen is similar in kind to that of figure 5. The other end of this particular specimen (figure 6) was much more pointed than the one illustrated. The length of the fossil was about five times its breadth, Figure 6 shows its broadest part. This fossil has been observed to occur in several layers, one over another and in close contact, in some fragments of the coal, and its characteristic "spots" at once reveal its presence when looked for.

Note on the above Fossil.—Can the pale colored "spots" represent holes or cavities in the original plant? Does the aspect of the bud-like processes along the bottom of figures 1, 2, and 3 suggest geminative excresences or sprouts? And, if this plant is not a unicellular one, to what group can it be assigned?



STRUCTURES IN COAL.

Plate V.

Fig. 1. Longitudinal section or plan of parallel rows of cells, gray, in color, embedded in clear black Pennsylvania anthracite. But in the neighborhood of a, a faint suggestion of organized cellular structure, nearly at right angles to the other, may be seen.

Fig. 2. Plan of part of several other rows of the same structure as in figure 1, and occuring on the same fractured surface of the same specimen of coal, at about one fourth of an inch to the left of the left hand end of figure 1.

Note. These organisms seem to be rare in the coal: they are the only specimens of the kind that the author has met with. Presumably they are of vegetable origin.

Fig. 3. An approximately vertical section of part of a bright, nearly black lamina in Pennsylvania anthracite, in dark gray coaly matrix. The specimen or fragment found, seems to be composed of some sixty separate bands or strands lying parallel with and practically in touch with one another. The point a, seems to be an edge or margin of the thing, the other end being broken off at b c. At d, something in the shape of an intruder appears and has created a deformity in the specimen at that place. Likewise a smaller disturbance appears near the middle of the figure.

Figs. 4, 5 and 6 show the character of the internal structure of the units as they are more or less distinctly revealed at or near to the several positions, e f and g respectively, Thus the specimen is apparently composed of but one kind of fibres or cells which are long rather than short, and towards the margins of the units become quite fine or hair-like in texture.

Note. This fossil seems to be scarce in the anthracite of Pennsylvania. In specimens of anthracite from South Wales, the author has observed rather similar forms and organization.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Fossil Flora of the Lower Coal Measures of Missouri. By DAVID WHITE. Monograph XXXVII, U. S. Geol. Surv. 1899.

In fullness of treatment, references, text and illustrations, and especially in its stratigraphic application, this is the most important work on Paleozoic plants yet published in this country. The only publication relating to American Paleozoic plants which can in any way be

compared to it is the Coal Flora, by Lesquereux, published by the Pennsylvania survey. To students and collectors of coal plants, especially in the Lower Measures, this book is invaluable, and it is a much needed example in methods of collection, study and publication. It will make clear the fact that little can be done in satisfactory classification and discussion of a Carboniferous flora without a great body of material for comparison, and without recourse to a very extensive literature. However discouraging this may be to many students, it is nevertheless true. The United States National Museum has already become the great depository of coal plant material in this country, and, with its great number of American types, will doubtless remain a center of systematic work in this field. The experience, the knowledge of the plants and the paleontological ability shown in this volume place its author in the lead among American students of Paleozoic plants. Whoever has attempted the determination of Carboniferous plant species with no other aid than the earlier memoirs on the younger Paleozoic floras realizes the insufficiency of a great part of the descriptions and the lack of data as to the localities or horizons of the fossils. A large proportion of the collections of the past, even those which formed the basis of the writings of Lesquereux, were so incomplete, so carelessly collected, their stratigraphical origin so generalized or indefinite, that they are largely valueless for correlation. What is imperatively needed is full collections of plant remains from exactly known horizons, and over wide areas. There remains plenty of work of the right kind to be done.

The book consists of 73 quarto plates, nearly all of them being photographic reproductions of plant remains, and 307 pages of quarto text. The first ten pages are given to introductory description of the collection and localities; the last 32 pages are general discussion of the geological significance of the flora and its correlation, while the rest of the book, 265 pages, is detailed description of the species. This biological portion of the work is admirable in its fullness, refinement and lucidity. The full bibliography and synonymy are evidence of the detail and difficulty of the study and of the scholarship of the author.

Nearly all of the plant material is from Henry county, Missouri, large in amount and covering many years of collecting, thus representing fairly the plant life of the coal basin.

Dr. J. H. Britts of Clinton, Mo., collected the larger part of the material, which was mostly derived from two horizons about 45 feet apart, and separated from the old Mississippian (Lower Carboniferous) land surface by less than 100 feet of sediments. The flora is "representative of that division of the Carboniferous resting on the Pottsville series in the northern and northeastern coal fields."

The species described, number 123, representing nearly all the common genera of the middle Carboniferous of Europe and America. They are distributed as follows: Algæ, 2; Fungi, 2; Ferns, 70; Equiseta 19; Lepidodendrids, 12; Sigillarids, 2; Tæniophyllids, 2; Gymnosperms, 10. The author draws attention to the preponderance of ferns, es-

pecially Sphenopteris and Pecopteris; he notes that with two unimportant exceptions all the plant species of the Missouri flora are at least varietally unlike the plants from the Pottsville series; and that a large proportion have a range through considerable thickness of American Mesocarboniferous, giving in consequence little aid in correlation of horizons. He finds, however, some local modifications of species having wide vertical range which do aid in correlation.

Of the 123 enumerated species 39 are peculiar to the Missouri flora, as compared with American localities, and of these, 24 are new species. For comparison with the floras of other basins in the United States 48 species of more limited vertical range are selected, and the final conclusion is that the flora represents a time subsequent to that of the lowest coals of the Lower Coal Measures of the eastern districts, as the Morris coal of Illinois, the Mazon Creek beds, and the Brookville and Clarion coals of Ohio and Pennsylvania, but probably an earlier date than the Darlington or Upper Kittanning of Pennsylvania and Ohio; also that the Henry County flora is nearly contemporaneous with the "D" or Marcy coal of the Northern Anthracite field, though possibly as old as the "C" coal. The unconformity in Missouri between the Henry County coals and the underlying Eocarboniferous surface represents no less time than was required for the deposition of the Pottsville series and the Clarion group of the lower productive Coal Measures, which have a thickness in southern West Virginia of 2,400 feet.

In comparison with European floras the author regards the Missouri flora as having a position between the Middle and Upper Coal Measures of Great Britain, or corresponding to the "transition beds," and to the upper zone of the Valenciennes coal field in the Franco-Belgian basin.

As evidence of the value of paleobotanical correlation, it is to be noted that the horizons in the British and the Westphalian coal basins which had been correlated by the European paleobotanists, are now found by the entirely independent studies of David White to be in each area also contemporaneous with this American flora.

As there is a strong contrast between the floras of the Pottsville series and those of the immediately overlying coals of western Pennsylvania and westward, and since the Lower Coal Measures of Great Britain and the Vicoigne (lower) zone of the Franco-Belgian basin are not known to be represented in the American bituminous region, the author suggests that the European beds may be represented in the variable strata of the upper benches of the northern Pottsville, and that they are probably represented by the Lower Coal Measures (Kanawha series) in the Kanawha region in West Virginia. The plants of the latter series, which he is now studying, promise to represent, in America, the Lower Coal Measures flora of England and Westphalia. (See below, page 59.)

Another interesting suggestion of the author is that many species, and even genera, of the Mesocarboniferous plants were evolved in-

dependently in different regions, under similar environment, and that they spread with great rapidity over northern lands. He is led to this idea by the essential contemporaneity of floras in nearly all the coal basins of the northern hemisphere, along with their wonderful resemblance in composition, or homogeneity, and especially the parallelism of appearance and disappearance of types, and the uniformity of their sequence. H. L. F.

Report on Fossil Plants from the McAlester Coal Field, Indian Territory, Collected by Messrs. Taff and Richardson in 1897. By DAVID WHITE, U. S. Geol. Survey, Nineteenth Annual Report, 1897-98, Part III, Economic Geology, pp. 457-536.

As this paper is the first description of coal plants from the southwestern margin of the Carboniferous basin, it has both biological and geological interest. The quantity of material is not inconsiderable, seventy-five plant forms being listed in the correlation tables. Seven new species and two varieties are described, mostly ferns, and the entire flora is described and discussed in the thorough and scholarly manner usual with the author.

The plants are from three widely separated horizons and consequently show decided biological differences, only two ferns being common to all three horizons. The highest horizon is a cut on the Missouri, Kansas and Texas railroad, one-half mile south of McAlester and about 2,000 feet higher stratigraphically than the McAlester coal, the middle horizon. The lowest horizon is 1,500 feet below the McAlester coal and is supposed to be identical with the Grady coal at Hartshorne.

Having such great vertical range and great botanical variation, a comparison of these floras with those of other and distant localities of the bituminous coal fields would be interesting and useful. Unfortunately there is very little available information for such comparison except from either the lower productive measures or the Permian. Over great areas of the bituminous regions, no collections whatever have been made and the few made are so incomplete as to have little correlation value.

The author regards the highest stage as much earlier than the Permian or upper barren measures; the middle, McAlester, stage as lying in the Upper Coal Measures (Missourian) of the Western Interior basin, and probably older than the Pittsburg coal; and the lowest stage, the Grady coal, as near the Mazon creek or Cannelton horizon of the lower productive Coal Measures (Alleghany series) and probably in the lower half. For the great thickness of these Coal Measures strata the author finds a parallel only in the Kanawha series of West Virginia for the lower half, and in the Joggins section of Nova Scotia for the remarkable dilation of the upper part.

Comparing the floras with European coal floras, the author confidently correlates the Grady coal flora with the Middle or perhaps the Lower Coal Measures of Great Britain, and with the Valenciennes

series of the Franco-Belgian basin. The McAlester coal flora he regards as Stephanian, representing the Upper Coal Measures of Great Britain, the Commentry flora of France, and the Saarbrück series in Germany. H. L. F.

Relative Ages of the Kanawha and Alleghany Series as Indicated by the Fossil Plants. By DAVID WHITE. Bull. Geol. Soc. Amer., Vol. II, pp. 145-178, March, 1900.

The value of fossil plants for the purpose of stratigraphic correlation has been questioned, and not unnaturally, considering the fragmentary character of the plant remains, the variability of the forms and the partial and indefinite character of the collections. The chief real difficulty is the lack of any standard paleobotanical section. With the immense material and literature now concentrated in the U. S. National Museum, David White has an opportunity for comparative study which he is improving. In this paper he virtually throws down the gauntlet to those who would disparage the value of plant correlation by boldly submitting it to a severe and crucial test.

As indicated in the title, the paper is mainly stratigraphical, the biological results of the author's study of the Kanawha coal flora being reserved for publication by the U. S. Geological Survey. He discusses here the relative ages of the Kanawha and Alleghany coal strata as shown by the fossil plants, and reaches a conclusion radically different from the accepted belief.

The geologists who have studied and described the Carboniferous strata in western Pennsylvania, Ohio and West Virginia have regarded the Kanawha strata and coals as the equivalent of those in the Alleghany valley. At the recent Washington meeting of the Geological Society, where this paper was read, with a fulness of illustration not here reproduced, the continuity and identity of the coal-bearing strata of the two regions was emphatically stated in the animated discussion of the paper. But David White finds that the characteristic plants of the Alleghany coals do not appear in the lower half of the Kanawha series, but do apppear in their proper sequence in the upper half. The flora of the lower half of the Kanawha section belongs as low as the uppermost portion of the Pottsville in the Pennsylvania or northern West Virginia regions and represents a life older than any found in the Alleghany series. The highest coal (Stockton) of the Kanawha series carries a flora similar to the lowest (Clarion) group of the Alleghany series. The author says: "The application of the names of the Alleghany coals to the several individual coals of the Kanawha series is in direct contradiction to the testimony of the fossil plants." The closing pages of the brochure are given to a concise and acute summing up of the argument.

Apparently the only way to settle the contention is by the continuous tracing of the strata. This will take time, but the result will be awaited with impatient interest. Fortunately all the persons directly interested are cordial friends, possessing excellent judgment and temper. H. L. F.

The Devonian "Lamprey", Paleospondylus Gunni, Traquair. By BASHFORD DEAN. 4to, pp. 30, 1 pl. (N. Y. Acad. Sci., Memoir, Vol. II., pt. 1, 1899.)

Dr. Dean gives a full account of the history and affinities of this most interesting fish, once thought to be a "baby Coccosteus." A restoration at page 8 exhibits that author's view of the structure of this remarkable vertebrate. He separates it as a class from Pisces under a new division of Arthrognathi.

In view of the great variation in size and form of the parts of this fossil, "Paleospondylus can hardly be looked upon as having attained its definite form. But if Paleospondylus be not the adult form, where, as Traquair asks, is the adult? Is it possible to believe with Dawson in its possible amphibian characters?" It "cannot well be regarded as a larval form of either shark, lung-fish or Teleostome; it is far more likely to prove, as Huxley believed, a larval Arthrodire." G. F. M.

Development of Agaricocrinus. By MARY KLEM. (Trans. Acad. Sci. St. Louis, vol. X, No. 7, pp. 167-184, 4 pls., 1900).

One of the beneficial results of getting the literature, species, and geological range of a great zoological group in orderly arrangement is the impetus it gives the subsequent study. No better illustration exists than that of North American Paleozoic Crinoidea as reviewed by Wachsmuth and Springer.

The little monograph on Agaricocrinus which has just appeared indicates how well large suites of limited groups may be treated to advantage, and how special studies within a prescribed field may be made to yield results that are lasting.

The author has given special attention to the ventral side of Agaricocrinus and its variation in a large series of a single species of which more than two dozen views are given. An attempt is made to find more satisfactory features than have been utilized heretofore for separating species. The conclusions reached are that "the best characters for specific separation are (*a*) the general aspect of the plates, (*b*) the external ornamentation of the plates, and (*c*) the anal area. The geological formation is also of value, as we may assume with perfect safety that fossils found in the Chouteau group belong to different species from those found in the Burlington or Keokuk."

The inquiry instituted by the author would point to the reduction of the forty-two species of American Agaricocrinus to ten. A considerable part of the monograph is devoted to criticising the late S, A. Miller's inordinate propensity to unnecessarily multiply species. After examining the synonymic lists, the question naturally arises, whether the pendulum has not swung too far the other way. Structural features that are almost generic in character are overlooked entirely and forms undoubtedly distinct thrown together under a single specific title. One must also question the last statement in the paragraph here quoted. It would be certainly very unsafe to assume that all forms from the Chouteau, Burlington and Keokuk limestones are necessarily specifically distinct.

C. R. K.

Geological Survey of Alabama; Report on the Warrior Coal Basin. By HENRY MCCALLEY, Assistant State Geologist. Pages xiii, 327: with 50 figures in the text, 7 plates and a map, 1900.

The area here described comprises about 3,000 square miles in northwestern Alabama, drained by the Black Warrior river and its tributaries. It has twenty-three coal seams, which, in their varying development, have an aggregate thickness from about 10 to 115 feet. Seventeen of the seams have extensive workable outcrops, the maximum thickness attained by a single seam being 16 feet. Although the first mining in a systematic manner was so recent as the year 1872, the progress and present importance of the coal production of this district place it in the front rank with the great bituminous coal mining districts of the world. Its output during the year 1898 was 5,556,532 tons. The most of this coal is used within the State of Alabama, largely in the neighboring city of Birmingham and its vicinity; and nearly 2,000,000 tons of it, in 1898, were made into coke for iron ore smelting. W. U.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Adams, Frank D.

Sir William Dawson. (Can. Rec. Sci., vol. 8, pp. 137-149. Jan., 1900, portrait.)

Ami, H. M.

Notes on some of the formations belonging to the Carboniferous system in Eastern Canada. (Can. Rec. Sci., vol. 8, pp. 149-163. Jan., 1900.)

Bailey, E. H. S. (G. P. Grimsley, and)

Special report on Gypsum and Gypsum cement plasters. Univ. Geol. Surv., Kans., vol. v. Topeka, 1899.

Bayley. W. S.

The Sturgeon River Tongue. (Mon. 36, U. S. G. S., pp. 458-486, pls. 51-53.)

Clarke, John M.

The Paleozoic faunas of Para, Brazil. 1. The Silurian fauna of the Rio Trombetas; 2. The Devonian Mollusca of the state of Para. (Arch. do Museu Nacional, Rio de Janeiro, vol. 10, 1899. Author's English edition, pp. 127, 8 plates.)

Clements, J. M. (and H. L. Smyth).

The Crystal Falls Iron-bearing district of Michigan. U. S. G. Surv. Mon. 36, pp. 512, 53 plates, 1899.

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*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

Dawson, George M.

Summary report of the Geological Survey Department for the year 1899. Geol. Surv. Can. Sessional paper No. 13a, pp. 224. Ottawa, 1900.

Gould, C. N.

Phases of the Dakota Cretaceous in Nebraska. (Am. Jour. Sci., vol. 5, pp. 429-433. June, 1900.)

Grabau, A. W.

Siluro-Devonic contact in Erie county, New York. (Bull. Geol. Soc. Am., vol. 11, pp. 347-376, pls. 21-22. May, 1900.)

Grimsley, G. P. (and E. H. S. Bailey.)

Special report on Gypsum and Gypsum cement plasters. Univ. Geol. Surv., Kans. vol. v, Topeka, 1899.

Haworth, Erasmus.

Relations between the Ozark uplift and ore deposits. (Bull. Geol. Soc. Am., vol. 11, pp. 231-240. May, 1900.)

Heilprin, Angelo.

The shrinkage of lake Nicaragua. (Sci. Am., Sup., May 19, 1900.)

Knight, Wilbur C.

Jurrassic rocks of southwestern Wyoming. (Bull. Geol. Soc. Am., vol. 11, pp. 377-388, pl. 23. May, 1900.)

Lane, A. C.

Elevation of Saginaw. (Mich. Miner, vol. 2, p. 19. June, 1900.)

Lane, A. C.

The Geothermal Gradient in Michigan. (Am. Jour. Sci., vol. 4, pp. 434-438. June, 1900.)

Ladd, Geo. E.

A preliminary report on the clays of Georgia. (Bull. No. 6, Geol. Surv. Ga. 1898.)

Leverett, Frank.

The Illinois Glacial lobe. Mon. 38, U. S. Geol. Surv. pp. 817, 24 plates. Washington, 1899.

Logan, W. N.

A North American Epicontinental sea of Jurassic age. (Jour. Geol., vol. 8, pp. 241-273. April-May, 1900.)

Matthew, E. B.

Granite rocks of the Pike's Peak quadrangle. (Jour. Geol., vol. 8, pp. 214-240. April-May, 1900.)

McCalley, Henry.

Report on the Warrior Coal basin. Geol. Surv. Ala., pp. 327, 7 plates, map. Jacksonville, Fla., 1900.

McCallie, S. W.

A preliminary report on the Artesian-well system of Georgia. Bull. No. 7, Geol, Surv. Ga., 1898.

Preston, H. L.

New meteoric iron from Oakley, Logan county, Kansas. (Am. Jour. Sci., vol. 4, pp. 410-412. June, 1900.)

Schuchert, Chas.

Lower Devonic aspect of the Lower Helderberg and Oriskany formations. (Bull. G. S. A., vol. 11, pp. 241-332. May, 1900.)

Smyth, J. L. (J. M. Clements and)

The Crystal Falls, Iron-Bearing District of Michigan. U. S. G. Survey, Mon. 36, pp. 512, 53 plates, 1899.

Stevenson, John J.

Edward Orton. (Jour. Geol. vol. 8, April-May, 1900, pp. 205-213.)

White, David.

Fossil Flora of the Lower Coal Measures of Missouri. U. S. Geol. Survey, Mon. 37, 1899, pp. 464, 73 plates.

Williams, Henry S.

Silurian-Devonian boundary in North America. (Bull. G. S. A., vol. 11, pp. 333-346, May, 1900.)

PERSONAL AND SCIENTIFIC NEWS

Prof. W. M. Rice, of Wesleyan University, will attend the International Congress at Paris, taking part in several of the excursions.

Dr. Lewis G. Westgate, of Evanston, Ill., has been elected professor of geology in the Ohio Wesleyan University at Delaware, Ohio.

Dr. H. Foster Bain, recently assistant state geologist of Iowa, who has returned from Idado Springs, Colo., goes to Joplin, Mo., to undertake a reconnoissance of that zinc field for the U. S. Geological Survey.

The Popular Science Monthly will hereafter be published by Messrs. McClure, Phillips & Co., and edited by Dr. J. McK. Cattell, professor of psychology in Columbia University and editor of "Science."

Prof. C. M. Hall, of the North Dakota Agricultural College, has been appointed to conduct a topographical survey of North Dakota, under the direction of the United States Geological Survey.

Prof. J. E. Wolff, who has spent most of the last winter in study in Germany, is expected to return during the latter part of August, and to resume his work at Harvard University, next October.

Mr. Alexander N. Winchell, of Minneapolis, who has been the last two years studying at Paris in the laboratories of Profs. Lacroix and Hautefeuille, has been elected professor of geology and mineralogy in the new Montana School of Mines, at Butte, Montana, and will return in time for the opening of the school in September.

The New Work on the Glacial Geology of New York state, just begun by the state survey, will deal at first with the history of the Hudson valley, of the erosive and constructive action as shown by Long Island and the valley of the river farther north, of the submarine trough to the southeast, etc. At present Mr. Woodworth is engaged in the vicinity of Oyster Bay, Long Island, upon a rather complex series of deposits.

The recently Established American Museum Journal aims to be "a popular record of the progress of the American Museum of Natural History" of New York. Its evident purpose is to make known in an agreeable and non-technical manner whatever is of general interest in the scientific work, expeditions, collections, and current accesssions of the Museum. The more noteworthy features of Number 1 are its excellent illustrations, the incisive sketch of the early history of the institution, the account of the Museum's ethnological work in northeastern Asia, the description of a recent gift of fossil fishes, and the article on the Museum's work in the long-buried cities of Mexico and Central America. Information regarding lecture courses and scientific publications is to be given every month.

The Engineering and Mining Journal of June 9th published the full tables of mineral and metal production of the United States in 1899 as prepared for the "Mineral Industry," Volume VIII. This production, valued at the mines or furnaces, amounted to $1,211,361,861, the largest amount on record for the United States or any other country. Deducting certain necessary duplications, the net value of the mineral production in 1899 was $1,118,780,830, against $799,518,033 in 1898, showing an increase last year of $319,262,797, or 39.9 per cent. This great amount came partly from the increase in quantities and partly from general advances in values. The United States last year was the greatest producer of coal, salt, iron, copper, silver and lead in the world; also of many of the less important metals and minerals.

The extent of our production is shown by the figures, which include 252,115,387 short tons of coal, 13,400,735 long tons of pig iron, 581,319,091 pounds of copper, 217,085 tons of lead, 129,675 tons of zinc, 57,126,834 ounces of silver, and $70,096,021 in gold.

Work of the United States Geological Survey in Alaska. The following plan for Government work in Alaska during the season of 1900, submitted by the Director of the U. S. Geological Survey, has received the approval of the Secretary of the Interior.

Exploration, Copper River District.

Chettyna party.—Reliable reports by officers of the Geolo-

gical Survey and of the military surveying parties in Alaska, as well as from private sources, indicate the existence of a probably important copper district on the tributary of the Copper river called the Chettyna, south of the Wrangel Alps, and also on the headwaters of the Copper and Nabesna rivers, north of that mountain range. Previous explorations have accomplished all desirable reconnaissance work in this region, and the value of the economic resources appears to justify more detailed topographic and geologic surveys.

It is therefore proposed that a party under Mr. F. C. Schrader, geologist, with one assistant geologist, and Mr. T. G. Gerdine, topographer, with assistant topographer and six camp hands, should make a topographic and geologic survey of the valley of the Chettyna river, comprising an area of about 3,000 square miles, on a scale of four miles to the inch with sketch contours. This work is to be connected with the Coast Survey work near Valdes, and if practicable, explorations are to be made by the geologist between the valley of the Chettyna and the southern coast parallel to it. This party will leave Seattle, May 25.

Surveys in the Seward Peninsula.

Cape Nome district.—The most immediately important work to be done in Alaska during the coming season is the detailed topographic and geologic survey of the Cape Nome district and its extensions in the Seward peninsula. According to the best information available, surveys intended to define the extent of the gold-bearing area in the southern portion of the Seward peninsula between Cape Nome and Fish river should cover an area between 3,000 and 4,000 square miles in extent. For this survey it is proposed to organize two parties, one topographic and the other geologic.

The topographic party will be placed in charge of Mr. E. C. Barnard, with one assistant topographer and a sufficient number of camp hands to permit of distinct operations in the field by the two officers. This is necessary in order to cover the required area in the given time. The survey is to be made on the scale of four miles to the inch, with sketch contours, in a manner similar to that executed by Mr. Barnard in the Fortymile district in the summer of 1898. In co-operation with the Coast & Geodetic Survey, it has been arranged that Mr. Barnard's party shall complete the triangulation between Golofnin bay and Port Clarence, work for which the Coast Survey would otherwise have to organize an independent party, and in return for which transportation is afforded the parties of the Geological Survey from Seattle to Golofnin bay, on the steamers of the Coast Survey, leaving Seattle about June 1.

The geological party of the Cape Nome district is placed in the charge of Mr. Alfred Brooks, with two temporary geo-

logic assistants. Mr. Brooks' investigation will cover the area surveyed by Mr. Barnard's party from Fish river to Cape Nome and Port Clarence, and also reconnaissance of the Cape York district. It is proposed that he will determine the extent of the gold-bearing formations and trace out the conditions of occurrence of veins from which the placer gold has been derived.

The trend of the gold-bearing belt of Cape Nome and vicinity appears to extend northeastward across the Seward peninsula toward Good Hope bay and the Keewalik river. It is therefore proposed to extend reconnaissance work along this trend and the following additional operations are recommended:

Reconnaissance of extension of Cape Nome Gold Belt.

This party will consist of Mr. W. J. Peters, topographer, and Mr. W. C. Mendenhall, geologist, equipped with a sufficient number of camp hands and canoes for exploration, with topographic and geologic reconnaissance. It is understood that they can be conveyed by a Coast Survey steamer to Good Hope bay, where they may be landed and whence they may proceed with their equipment to survey the northeastern portion of the Seward peninsula, returning across the neck of the peninsula by Buckland river to Norton bay.

Preparation for Exploration in 1901.

Reconnaissance, Koyukuk River to Arctic Ocean.—The head-waters of the Koyukuk river north of the Arctic circle were partially explored by a party under Mr. Schrader in the season of 1899. Between the Koyukuk and the shores of the Arctic ocean there is a little known district into which exploration should be extended. It is impracticable that a party loaded with supplies for a season's work should leave Washington and reach the upper Koyukuk sufficiently early in the season to be assured of adequate results with certainty of escape in the autumn, but if supplies be put in by steamer on the Koyukuk during one summer, the men, with light outfits, may proceed by sledge, to the starting point the following winter and be ready to take advantage of favorable conditions of travel in ascending rivers on the ice early in the spring, and in descending them after the ice is broken up. To accomplish this object it is proposed that supplies shall be sent in by steamer during the summer of 1900, to be stored at the mouth of the Allen Kakat river. Whence the proposed route is up the Allen Kakat to the divide by which it heads against streams flowing north to the Arctic ocean, and thence down such a stream to the Arctic and along the coast westward and southward until the party shall be picked up.

E. D. Cope

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THE

AMERICAN GEOLOGIST.

VOL. XXVI. AUGUST, 1900. NO. 2

THE LIFE AND LETTERS OF EDWARD DRINKER COPE.

By PERSIFOR FRAZER, Philadelphia, Pa.

Plates VI-XV.

Prefatory Note.

The following memoir was based upon letters and other writings of Edward Cope in the belief that in no other way than through his own pen could so just an idea of his character be given. The main sources of these writings were the letters to his immediate relatives, kindly loaned by his wife, his sister, and his cousin (the latter's husband), together with a comparatively small number preserved by the present writer, who takes this occasion to thank these relatives publicly, as he already has privately, for the assistance thus afforded. The original memoir, as originally prepared, contained a chronological table of all of Prof. Cope's publications, and was five times the length of the accompanying sketch, even without counting a cross reference alphabetical index which would have added half as many more pages. For various reasons, these parts have been taken out. The cross-reference index is being published by the Mexican Society "Antonio Alzate"; and the letters themselves have been curtailed (though with reluctance) to a fraction of their original space.

It was intended to reproduce the entire childish journal of a voyage from Philadelphia to Boston, because there is a very touching interest in the occasional wise and cautious conclusions drawn by this boy of seven, but space was lacking. One is witnessing in these early writings the rapid growth of a mind which was destined to become great. It is also most instructive to note how accurately the eye saw and the hand learned to portray. There is, without question, a connection between the success in his chosen profession of a naturalist, and his facility for accurate delineation of what he sees or thinks he has seen. Indeed much that is false in the latter disappears in the attempt to represent it. Eminent students of nature are usually proficient in the art of delineation, as many conscientious artists are conversant with the nature from which they draw their inspiration.

The following memoir is a condensed digest of the larger one, but it is hoped that it will not entirely fail to justify its title, which promises an unconscious autobiography in the collection of the subject's writings during fifty years.

The dominating motive of Cope's character was reverence for pure religion and pure science. In his view these occupied totally different fields; were not in conflict, but on the contrary each was of assistance to the comprehension and the proper expression of the other. Yet, although he acknowledged that the human faculties called into play by each were different at the present time, he never abandoned the belief that one day they would be the same, and that in the progress of science the proofs of a future life and of a beneficent Creator and Savior would be reached. Few men have succeeded so well in concealing from any one friend or relative, however close, all sides of his multiform character. At his death, when his letters to many different correspondents were brought together, there was not one of those who knew him most intimately but was surprised at a phase of thought developed to some other which had been unknown to the first. His scientific friends were amazed at the profound religious feelings which he had always exhibited to his nearest relatives; and these at the broad views of social problems which he had imbibed in his intercourse with the world.

Toward science his devotion was unbounded, and his attitude towards the organizations for its prosecution was that of exalted patriotism. The cry "Greece for the Greeks!"; "France for the French!"; "America for the Americans!"; was with him "Scientific Societies for Scientific men." He loathed the servility which permitted, often by unworthy means, the election to membership, and even to the high offices in such organizations, of those whose only claim was wealth or political influence without regard to the manner of its acquisition. He despised nest-stealing cuckoos, and jackdaws ridiculous in official plumes filched from those who had earned them.

He was indignant at the mendicant policy of some societies, padded with wooden members owing to the absence of all requirements but those which an officer of one of them jocosely described as "five dollars a year, and present immunity from compulsory attendance in the penitentiary"; societies which persisted in what has been called "post-obiting" supposed Mæcenases, i. e. electing them to high office, regardless of their mental, or moral equipment, in order to benefit by some part of their hoard; and that too in the face of repeated examples that the reward for such undeserved honors was usually a generous monument to the eminence of the donor erected somewhere else. This curious habit of rewarding Peter for the services of Paul, has been, it is true, exhibited by some really scientific men who have left their collections away from the scenes of their labors and honors; but Cope's view was that the collections of scientific men should be left to the institutions where their knowledge was acquired, and whence it was disseminated; and no disappointment was greater to him than that of being obliged to see the best part of his own collection of a life-time pass away from his native city and the society in whose halls he had performed most of his work. Still greater would have been his grief could he have foreseen that the remainder, which he had devoted to the foundation of a chair in the Academy of Natural Sciences of Philadelphia was also lost to that institution. One of his noteworthy characteristics was that he never forgot the respect due to the humblest of the societies to which he belonged, and

would exert himself as earnestly to keep up the standard proposed in the organization of a temporary naturalist's club, as in that of the most exclusive body of scientists. He protested against stuffing institutions with persons who spent the time at meetings; as he used to say, in wrangling over questions of re-tinning the roof, of bedevilling some real worker, or of housing a body already sufficiently housed, but insufficiently supplied with publication facilities; and he often repeated that the most important scientific institutions of the old world proved their value in their publications and not in their buildings. The present writer shared these views, and this fact formed an additional bond of sympathy between him and the subject of this memoir.

We may be sure there were always rivalries, and even bitterness among the "illuminati," as among all others; but it is doubtful if in any previous epoch were to be found so many liliputian Neros presenting their brows to be crowned with bay by their obsequious sycophants, or the offices of "learned societies" so largely filled with professional failures, and the shifty disciples of personal expediency.

These classes have the numerical strength, and consequent ability, to harass any one who may excite their displeasure. They like to keep the offices filled with their own kind and to ignore men like Cope, Leidy, and Hunt either permanently or for years. It was this state of things that Cope pictured in a satirical sketch called

"Some Points || in the || Zoölogy and Geology of Glycaphuatl || by Robert Ramrod, A. E. C.", from which the following are extracts.

"Having recently returned from a somewhat thorough examination of the state of Glycaphuatl, I hasten to present to my readers some of the more important results of my observations. The region, I state in advance, lies on the east coast of the Caribbean sea, from which it is separated by the straits of Toothaecan, a region of perpetual calm owing to the jam that generally covers the water. The source of this substance will be shortly pointed out. * * The peculiarities of the people of Glycaphuatl, or Petromolgi, as they are usually called, deserve more than a passing notice. As may be inferred from the above, they have no backbone or indeed bones of any

kind. When they go out they lean on each other for support, a group of three leaning on one in the centre, whom they also support by their mutual pressure. Two are sometimes seen leaning on one in the middle but this is rare, cliques of more than four being more numerous than those of smaller numbers. A few of the people, here and there, retain some ossification of the backbone, from which arises my suspicion that the race is descended from a backboned people and that they have degenerated through the eating of sugar. These backboned people are disliked by the others, who are apparently jealous of them, and obstruct and interfere with them in every possible way. They have a system of laws which are apparently designed to extirpate this class, for they compel people who perform any labors by their own exertions to prove at every turn that they are not stealing or lying. In the case of the cartilaginous people these laws are inoperative, first, because these people rarely do anything but eat sugar; and secondly, because as they go in cliques of four or more, they can always bring plenty of witnesses to prove anything they please. * * The result of this gelatinous state of Petromolgi is, that they are continually engaged in taking care of their feelings. They cannot bear contact with hard bodies, so they wear an innumerable quantity of cushions. Their mental feelings are equally sensitive. They are constantly struggling to avoid the consideration of difficult questions, and in general appear to have no opinions at all. * * Their only institute of learning is the Asineum. Here they have meetings once a year, and issue their proceedings called by-laws, once in five years. * * The zoölogy of Glycaphuatl is no less remarkable than the geology. The genera to which I gave the most attention are those which have been called Potatoblenna, Noodlodon, Gyascutus, and Holoprocta. In these remarks I must confine myself to the leading species of these genera: Potatoblenna suffocans, Noodlodon serribellimus, Gyascutus obstreperus, and Holoprocta apertura. The P. suffocans and N. serribellimus have been heretofore known by their popular names only, as the Boojum and the Noodlion. * * The Boojum consists of a series of large oval bodies, connected by a rope-like axis. * * Each of its larger segments is nearly filled with a gelatinous semi-fluid which becomes thick on exposure to the air. When it desires to capture an animal it simply squirts this fluid from certain repugnatorial pores in its sides, and covers the creature with it, more or less. As the fluid soon stiffens, the prey is unable to escape, and is quickly swallowed by the boojum."

Ernst Hæckel, in speaking of his great colleague to the writer, once said that he could quite believe the statement that Cope at the close of his career stood justly credited with the determination of one-third of all the accepted fossil vertebrate species of North America.*

For years while Cope was making the history of the various branches of science which his talents adorned, various enemies were traducing him; but whenever he turned upon them and demanded light, the baselessness of their attacks was exposed. His wish to emulate the patience of his great Master is expressed in one of his letters in which he adds quaintly "but even He denounced them" (the Jews) "sometimes." What Cope might have accomplished without the opposition which increased with his usefulness, can only be judged by what he did in spite of it.

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*In answer to an inquiry on this point Prof. Henry S. Osborn has had the kindness to send me a note from Dr. O. P. Hay, from which the following is an extract:

* * "According to my examinations of the fossil vertebrates I find that there are something more than 3200 species described from North America, and of these Cope has given name to 1115. That is he has named that many species which, with our present knowledge, must be accepted as good. They are distributed as follows: Fishes, 227; Batrachians, 73; Reptiles, 320; Birds, 8; Mammals, 487; Total, 1115." * * *

According to this estimate of Dr. Hay Cope's contribution to the species of North American fossil vertebrates has been 34.8 p. c., or nearly 35 p. c. of the entire number.

Edward Drinker Cope.

Born July 28, 1840

Died April 12, 1897

The branch of the Cope family to which the subject of this sketch belonged descended from Oliver Cope, who according to his grandson Nathan Cope, came from Wiltshire, England, about 1687, and settled at Naaman's Creek in the extreme north of the present state of Delaware.

In "The Copes of Wiltshire," printed in England (Cotswold 1881) by J. C. Biddle-Cope, a brother of Edward Drinker Cope, formerly created by the Pope the Marquis of Biddle-Cope, now "Cyprian Cope," for private distribution, the pedigree of Oliver is traced back as follows; Oliver s. of John of Chisledon and his wife Elizabeth; John of C. s. of Jno. of Wilts and his wife Margaret; John of W. s. of Edward and his wife Maud; Edward s. of Sir Anthony Cope of Bedhampton and his wife *Anne* (*Lady Anne Stafford*).

Sir Anthony of Bedhampton s. of Stephen Cope, Esq., of Bedhampton, Co. Hants, Sergeant of the poultry to Henry VIII and Edward VI, and Anne dau. and co-heir of Wm. Saunders, Esq.; Stephen C. s. of Sir William Cope, of Hanwell and his first wife Agnes Harcourt, co-heir of her father.) This same Sir William Cope, married a second wife, Jane dau. of Sir J. Spencer, of Hodnell, Kt., by whom he had a son Sir Anthony Cope Hanwell) Sir William s. of Alexander Cope and ? : Alexander C., s. of William C. and a daughter of W. Gossage of Spratton: William C., son of John Cope (of Denshanger, Co. Norhants in reign of Edward III. Twice high sheriff, five times Knight of the County in Parliament. Espoused the cause of Henry IV. Died 1447) and Joan (d. 1435).

It has been stated that Oliver Cope came to the shores of the Delaware from Wiltshire in England about 1687.

His grant of land is dated Sept. 8, 1681, and recites that William Penn of Worminghurst in the county of Sussex, Esquire, in consideration of five shillings, etc., conveys to Oliver Cope, of Awbry, in the county of Wilts tailor, two hundred and fifty acres of land within the province of Pennsylvania (see Deed Book, Vol. 3, p. 334, Philadelphia, Pa.). Oliver had four children of whom the youngest, John (born 1691) moved to "Bradford" (Bradford township, Chester Co., Pa., about one mile N. W. of the town of West Chester) about 1712. John and his wife Charity had eight children, of whom the sixth, Caleb, born Nov. 4, 1736, married Mary, daughter of George and Sarah Mendenhall, of East Caln township, Chester Co., Oct. 17, 1760, and removed to Lancaster, Pa., in 1761,

but before his death came to Philadelphia. While burgess of Lancaster in 1776, captain (afterwards major) André, who had been captured by general Montgomery, at St. Johns, Upper Canada, was sent with other British prisoners to Lancaster, where Caleb Cope offered them an asylum in his house, in spite of the popular excitement against them, which led to an attack upon it. He was a member of the Society of Friends and an opponent of war with England. In this connection it should be said that the historian of the family finds no authority for supposing that Oliver, the original settler, ever belonged to this society, though John, his son and father of Caleb, was a prominent member. Caleb had seven children of whom the fourth, Thomas Pim, was born Aug. 26, 1763: removed about 1784 from Lancaster to Philadelphia; and married Mary daughter of John and Rachel Drinker of the city by whom he had eight children of whom the seventh, Alfred, was the father of the subject of this sketch. In 1821 Thomas Pim Cope established the Cope packet line of ships trading between Liverpool and Philadelphia.

Alfred Cope married Hannah, daughter of Thomas and Edith Edge, of Chester Co., Pa., on October 23, 1839, and by her had three children: Edward Drinker (b. July 28, 1840), Elizabeth W. (wife of Philip C. Garrett, b. Nov. 15, 1841), and Mary Anna (b. April 19, 1843).

After the death of his first wife in 1843 Alfred married Rebecca Biddle Oct. 14, 1851, by whom he had one son, James Biddle Cope.

See "The Cope Family" by Gilbert Cope. King and Baird, Phila. 1861.

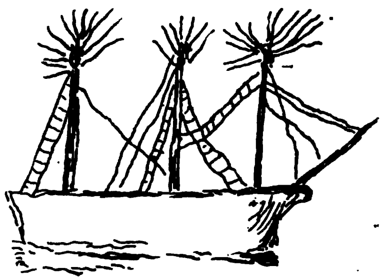
See also Americans of Royal Descent, Browning. (Porter and Coates.) Philadelphia. 2d Ed. 1891, p. 277, Pedigree LXX.

Edward Drinker was born in Philadelphia, July 28, 1840.

The earliest productions of his pen which the author has seen are dated in the year 1847. A collection of compositions on various subjects antedates his birthday of that year and a very creditably composed, written, and illustrated journal describing a voyage he made by sea from Philadelphia to Boston was commenced and completed in August or just after his seventh birthday.

Figures 1 and 2 represent two pages of this little journal with sketches of a lightship in the Delaware and a grampus off the coast. (Plates VII and VIII).

where the Ledge was.
The Ledge is a shoal



We past the the Brandy-
wine light boat after
night and pretty soon

FIGURE 1.

sides. One came close
along side of the ves-
-sel The captain ran
and got a harpoon
to catch one, but it was
too late They had
all swam away.

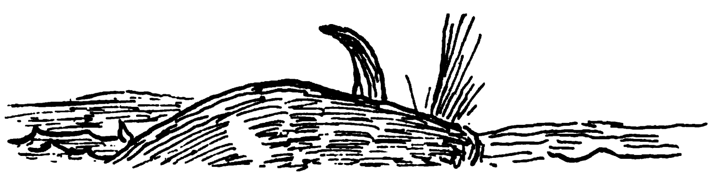
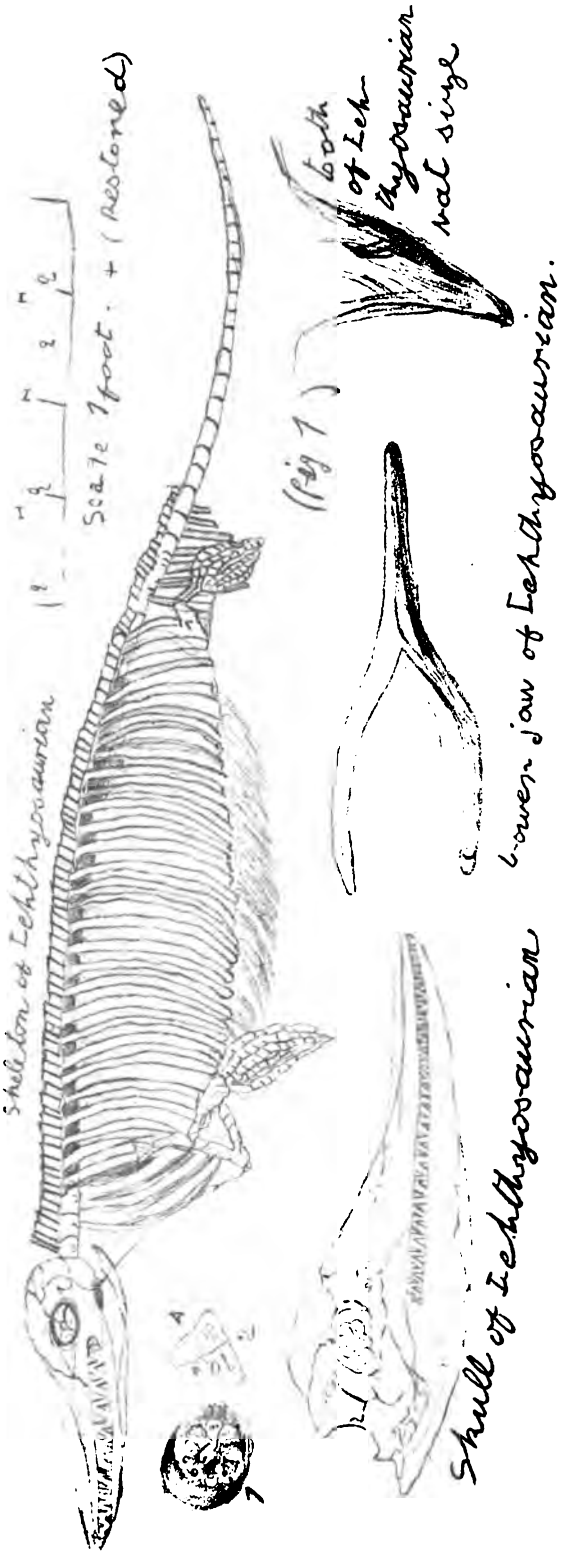


FIGURE 2.

14th three Fighting-Eagles,
which were gray, the reason why
people call them fighting Eagles, I
suppose is because they are great
fighters; they had hooked bills, and
~~[illegible]~~ sharp talons,— very well suited
for fighting.
15th a couple of birds called Serpent
eaters; I cannot remember the color, but
I think it was gray, it was an Eagle
too I think; it had a hooked bill and
strong talons, like all Eagles have.
I suppose it ets serpents, if not, I think
it would not be called serpent-eater,
16th a Golden Eagle, the color
of which is a dark mahoganey;
this bird is the largest of the



(1) THE EYE. (2) TWO OF THE SCLEROTIC PLATES: LOOK AT THE EYE, THEE WILL SEE THESE IN IT (AA) ARE THESE.

EDWARD DRINKER COPE.
(1850—Ten years old.)

The following excerpts are taken from an account of a visit to the Academy of Natural Sciences, then situated at the N. W. corner of Broad and Sansom Sts., contained in a paper book written and illustrated by Cope; because it gives the clearest insight into the habits of mind which finally produced the great naturalist. (Plate IX).

"On the 21st of the 10th mo. 1848 I, with some of my friends went to the Academy of Natural Sciences, and saw, firstly,

"Several small skulls of birds of different sizes and forms; some of them had red, black, and white bills. Among them were about five skulls of Toucans that had very large bills, which were of a brownish yellow around the mouth shading off into brown. Likewise about four skulls of horn-bills that had large bills too, with a large horn that began at the root of the bill, going along parallel with it and then turning up in a rounding way.

2ndly,

"A skull of an elephant, that was about two feet high from the bottom of the lower jaw to the top of the head and one foot broad: the tusks had been sawed off; I suppose for ivory. etc., etc.

"3rdly, Two large cloven-footed legs about six feet high which were very dark. etc., etc.

20th. Some saurians which were fossil skeletons that were found in the rocks of England, but it is very curious that they are monstrous sea lizards. (Plate X.)

In the centre of the room, there were two rows of fossils; such as ammonites, starfish etc.

Second story.

First, a great collection of human skulls of ancient Egyptian, old Peruvian of the Inca race, Indian, and idiots of different nations; some of them were curiously shaped, having mouths that projected very much, etc., etc.

14th, three fighting eagles which were gray, etc., etc.

The foregoing sketch (Plate XI) accompanied a composition on caterpillars written in his ninth year.

The accompanying portrait represents the subject of this sketch at ten years of age. (Plate XII.)

At the age of 13 he entered the Friends' school in Westtown.

A letter of September 27; 1853, from the school, is written on the back of his report of which he says: "It is not any too good, thee can see." In fact it is not, and what is curious is that physiology is the only subject in which not a single les-

son is reported as having been well said, whereas there were 15 well said in mathematics; 3 in astronomy, 9 in Latin, 7 in etymology, 4 in grammar, 7 (all) in scripture, and 2 in chemistry. He writes:

"I caught a large water snake or water wampum as they are called here—one of the Colubers in Brandywine, and brought it home. It was about as long as my leg, but very thick for its length, being somewhat more than two inches in diameter in one place. I afterwards found that it had eaten a large bull frog which somewhat increased its natural thickness. The people told me it would bite me, for everybody almost about here thinks water wampums are poisonous, and, indeed the way it struck at me scared me a little, but I soon convinced myself it was not, by examining its mouth which wanted fangs, and as all non-venomous have, it had four rows of small teeth in its upper, and two in its lower jaw, and two rows of scales under the tail," etc.

The pen and ink sketches of which reproductions are given in plates XIII and XIV, belong to about this period. They show remarkable skill in portrayal and confirm the impression that the qualities which go to make a great naturalist are likely to produce a skillful wielder of the pencil and brush. At least hosts of distinguished students of nature have been expert and accurate draughtsmen, among them Leidy, Cope and Hæckel.

In a letter from Jennersville, of May 15, 1858, at the age of nearly eighteen years, to his sister Elizabeth, he says:

"As usual, when I have no congenial company, natural history is my amusement and I have a good chance to study here. * * Probably at Westtown you may be interested in some new flowers, i. e. new to you. Here many interesting ones are found. The Nat. Ord. Orchidaceæ which is my pet, flourishes, and one nice one has so far rewarded my searches, it is Cypripedium acaule and is quite rare." * * "I will send you a plant by mail like T. H. sends cuttings—in peat moss, which is very light and would cost but little postage."

"I have rummaged up all the Violæ I could find—the results are, Viola cucullata (vars. sororia and reniformis) V. ovata, V. sagitatta, V. pedalta, V. palmata, V. pubescens, V. striata, and V. blanda. Can you show such a list? I have pressed these, and if any species not in this list, grow about Westtown, will you please take care to secure them?

"This morning I examined the nice little Krigia virginica (Compositæ) and yesterday Pedicularis canadensis, (Scrophulariceæ.) The woods are beautiful with Rhododendron (Azalea) nudiflorum and Thalictrum anemonoides is not yet gone. Trillium pendulum, a beauti-

Subf. 2 Megapodius

M. Freycinetii.[1] — rub.

— ripes. tumulus[2] (210). Duperreyi[2']

210

Subf. 3 Leipoa[2] +

L. ocellata[3]

Subf. 4 Alecthelia[4]

A Urvillii[5]

Rallidae (Sw.)

I Genus 3: Palamedia

P. cornuta[6] — cristata[7]

Screamers

211

Genus 4: Dicholophus

D. cristatus[8]

Genus 5: Psophia

P. crepitans[9] — leucoptera[11] — viridis[13]

Genus 6: Crax Curassows

C. Alector[10] — globicera[11]

— rubra[12] — carunculata[14] —

Yarrellii[13]

212

Subf. 2 Ourax 213

O. erythrorynchus[15] (213)

O. mitu[16] (215)

213

- Carolinensis[9] discors[2] - gloritans[3]
- inornatus[4] - fredensis[4] - formosa[5] - Jav-
-anensis[6] ~~fera~~ - obscura[7] - maxima[8].

Sub G. | 5 Dafila (244

D. caudacuta[9] - Capensis - urophasianus 244 a

Genus | 4 Tadorna (245) Sheldrakes

T. Bellonii[10] - moschata[11] 245

- rutila[12]

Sub F. | 4 Fuligulinae Sea Ducks

Genus | 1 Somateria Eiders 246

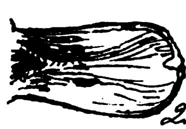
S. spectabilis[13] (246) - Stelleri[14]
- mollissima[15]

Genus | 2 Oidemia (247) Scoters

O. perspicillata[16] (a) - nigra[17] (b) 247

- fusca[18] - leucocephala[19].

Genus | 3 Fuligula Pochards



F. ferina[19] - marila (248) 248
- valisneria[20] - rufina[21] - ferruginea[22]
- cristata[23] - Gesneri[24] - rubidus[25] - rufi-
-torques[26] - Labradora[27] - nyroca[28] - ferinoides[29]
- mariloides[30] - caryophyllacea[31]

fully delicate plant with a sweet smell (Ord. Smilaceæ) is pretty com mon in one or two places about here—have you seen it yet?

"The distinctions of the orders are very nice; Ord. Labiatæ you know is this way" (sketch.) "4 little nutlets. I have been examining some of the Borraginacea, (Lithospermum and Mertensiæ) and the ovary consists of 4 hard achenia, this way," (sketch); "the plan is" (sketch). "The corolla is not labiate either. Two Cardamines (Cruciferæ) are common about here, also Dentaria laciniata a pretty little thing and not very common. Doubtless you have Senecio aureus; the meadows are golden with it in some places. The two Veronicæ, serpyllifolis and peregrina are found about here; they are delicate little plants, Nat. Ord. Scrophulariaceæ. This order in its corolla, stamens and pistils is much like Labiatæ, but the ovary is different, being a two celled capsule, thus," (sketch) "or, a section" (sketch). "Paulonia imperialis is a good example of a Scrophularious capsule. I mention these that you may be able to form some idea of whether the Westtown flora is anything like ours: I would like to know what you find. Have you Dielytra cucullaria growing about W - I wish, if it is common, you would put a sprig in your answer. Corydalis glauca and C. aurea are two nice little plants of the Order Fumariaceæ, but I have not found them wild here." * * * In this letter he says "I do like a little feeling such as they had" (the letters of his sister Mary Anne) "It does well enough for boys to be stiff about their feelings , but girls and women! that is their department".

June 10, '58.

"I have the faculty of making something to do—if for no one else, for myself. I study nurserying, ornithology, herpetology, botany and flageolet-ology."

August 22, 1858, to P. C. Garrett.

"Last 4th, day * * I took my gun, and went off to a woods not far distant * * * I penetrated the gloom of the forest primeval in search of its feathered inhabitants. I first came upon a family of the beautiful Cardinal grosbeak (Cardinalis virginianus) which I took much pleasure in watching, and one of which I shot. But it fell right into the midst of a wide creek, so that in order to secure it I was compelled to strip and swim. Just as I crawled out a splendid male flew by, and lit near at hand, which was so much more brilliant than my specimen, that I thought, I must have it; so "in naturalibus" I banged away and soon had the beauty. I resisted the temptation to shoot a fine green heron or "fly up the creek" (Butorides virescens) and wound my way to where I heard cries of distress proceeding from my little woodland pet; the red eyed Vireo (Vireosylva olivacea). I found the casus belli to proceed from a mischievous flock of blue jays (Cyanocorax criatatus) who seemed bound to do some injury to Vireo or his family. These jays are great oddities, perfect buffoons; one while their notes are like an infant screaming; then like a large number of people engaged in low but animated gabble. In a minute you hear a metallic ring like the sound of machinery, when as though alarmed at your presence they take wing with loud cries. I left them

unharmed and went farther on where I shot a species of Tyranula or Pewee, which has interested me much on account of some peculiarities of plumage in which it differs from the species which I am acquainted with. Deeper in the wood I came across what I always like to meet, a flock of titmice (Parus), nuthatches (Sitta) and wood-warblers (Sylvicola, Vermivora, etc.) which in spring and from this time till towards winter, perambulate the woods in busy and active search for their insect prey. The Sylvicolas, of which the flocks are principally composed, are with but few exceptions migratory, being seen here in spring and fall only, breeding northward, and wintering in the West Indies, Guiana, etc. Many of the species are very elegant. The little flock of which I speak was making a great fuss and noise about something in the top of a tall hickory; which I at last made out to be the form of an owl, which looked at me most singularly with its great eyes; and its keratoid (keras eisos) tufts of feathers added to its odd appearance. After a little debate as to the necessity of taking the life of a bird so really useful, I put the stock to my shoulder, and he was soon wheeling down from the tree. I was pleased and surprised to find it a species which I had not seen before—Ephialtes nævia "The mottled owl." The owls (Strigidæ) form the third and last family of the Raptorial order. The present genus (Ephialtes) comes in the sub-family Buboninæ of which Bubo is the type (containing (e. g.) the "great horned owl" B. virginianus and others) and which contains but two other genera (Lophostrix and Ketupa). Now in this sub-family Buboninæ, I can show thee a rather pretty example of the carrying out of the quinarian and representative theory, in nature. True the genera in it are but four, but many owls are yet to be discovered; besides, an author, not a quinarian, has made a fifth genus from an aberrant species of Bubo; "Urrua" from B. Bengalensis, and it may be a good genus, especially as the deficiency occurs between Bubo, and the East Indian genus Ketupa. However, these are the analogies.

1. Gen. Bubo.	size large; form preeminently raptorial, i. e. the instruments of destruction best developed.	analogous to order Raptores.
2. Gen. Ephialtes	size small; species very numerous instruments of destruction less developed. Geographical distribution very general.	Insessores.
3. Gen. Lopostrix	Head with a very large crest.	Rasores.
4. Gen. Ketupa	legs very long and slender; bill ditto for an owl.	Grallatores
5. Gen. ?		

The last form connecting with Bubo and representing the Natatores or aquatic type, not certainly known. The first two and the last,

thee can readily perceive, and the third too if thee knows that a peculiarity of the Rasorial order, and its representatives, consists of crests, topnots, horns (as in the Ruminantia, and Rasorial type among mammalia) and also eyes like spots, and rich brown markings which thee knows run through partridge, grouse, pheasant, turkey, peacock, guinea fowl, and hundreds of others.

"Thus it is that four of the orders of birds are typified among a subdivision of the owl family. The comparing of the five orders of birds with the same of mammals brings out some pretty results thus—

Raptores	Food animal; habits raptorial; structure most perfectly adapted for destruction.	Feræ. (carnivorous)
Insessores	Food omnivorous (cacographia.) Structure formed for arboreal exercise; i. e. organs of prehension best developed.	Quadrumana.
Rasores	Food of grains and grasses; form typically bulky; furnished with creata (manes) spurs (horns) etc. etc.; habits domestic and most useful to man.	Bruta (Ruminantes) etc.
Grallatores	Snout (beak) slender; contains the most imperfect creatures of their kind and the smallest; swift of foot.	Glires (Rodentia)
Natatores	Habits and character of food, aquatic; head very broad; extremities short and small.	Cetacea

The circle, i. e., the connections between the last and first is completed among the birds by such as the gulls and albatross which combine the webbed feet and aquatic habits and food of the Natatores with the powerful structure and raptorial manners of the Raptores. Among the mammals it is completed by the Seals, which belong to the Feræ but have many points of resemblance to the whales (Cetacea). And there are just such links between nearly all the Orders, Families, Genera, etc., etc., throughout Nature, whether among animals or plants."

The following year (July 7, 1858), a letter of eight closely written pages from Jennersville discusses with his father the merits of a large number of trees for transplanting to the family place at Fairfield. It shows a vast acquisition of botanical information and ends with a classified inventory of 348

trees and shrubs, written clearly without a correction, and proving unusual care and industry.

June 24, 1859, near his nineteenth birthday, he wrote a very cheery and interesting letter to his cousin, Philip C. Garrett, containing remarkable passages, some of which have been already quoted in previous biographies.

"How beautiful were the blossoming laurels wasting in a measure their beauty in this lonely spot: there certainly ought to be more pains taken to cultivate them. Here they will plant a miserable Ailanthus or a bare Pavlonia, and neglect the aristocrat of the wilds—this very handsomest shrub in America. The ferns grow here in great luxuriance and beauty, and when they are pretty no plants, I think, can excel them; the deep green and leathery Polystichum, with its little peltate indusium (the scale that covers the sorus or bunch of sporangia) of which I found a remarkably cut variety; the light Sitolobium as delicate and feathery as if traced by the hand of an embroiderer with little cups to hold the sporangia whose lid is a fold of the border of the frond; the maiden-hair whose rich beauty thee well knows, the noble Osmundas which with certain kin (e. g. the Lygodium or climbing fern) * * stand aloof from the great assemblage of ferns in possessing a peculiar structure the sporangium, and in not bearing them upon the back of the frond but in tall fertile spikes (an altered frond) * * . The mosses and lichens looked most beautiful too. * * * I saw more beauties among the latter than I thought existed; and most of them bore numerous little shields often delicately tinted" * * * "I stopped at a little stream that ran down from the hill to drink, and laying aside my rod, gun, and other encumbrances began to follow it up. I soon found it to be a most exquisitely romantic little run. It flowed over large flat shelves of rock, sometimes between high banks of the same material overgrown with moss and ferns. At one place it made a short turn, at the upper end of which the water came dashing over a rock ten feet high, the laurels interlocked overhead and still higher the forest trees. Here I sat down. There was no sound but the splash of the little fall; not even a bird, and the fitful flashes of tempered sunlight gleamed on the dancing water but to gild the bright green of the tufts of aquatic moss that waved in the current. What a spot to start up some timid nymph of the fountain, or some Dryad who had come to bathe in the liquid crystal! Nor did I forget to wish for a mortal Nymph, who should have a mind to appreciate and a physique to endure this spray sprinkled moss cushioned adytum of Sylvanus."

A short distance further up the little rivulet the embryo naturalist dominates the poet, and he captured two salamanders, of species he had never before seen alive. One, Spelerpes

longicauda) "the type of the sub-family Spelerprinæ which I attempted to characterize in a paper published in the Proceedings of the Academy of Natural Sciences."

"It is now evening, and such a one as would delight thy peace loving fancy. The temperature is delightful, and Zephyrus breathes so gently as scarce to disturb an aspen leaf. There is no sound of man; everything is in perfect repose except the cricket trilling its soothing note, and the toad whose sad cry comes from the swamp. As the west grows grayer and the last glow of sunset disappears, the light mists rise and spread over the low meadows like a veil upon the sleeping grass, while the dark shade of the willows is spangled by the sparks of the fire fly, which rise from their dismal concealment and light timid benighted fays—for there is no moon. How soothing and calming to look out upon this silent view, terminated by the dark woods upon the horizon. It makes one feel at peace with oneself and everyone else; and how gently you can glide into dreamland with a soft breath fanning your cheek like the wing of a passing angel."

"Dr. Leidy is getting up a great work on comparative anatomy which is to be the modern standard. Such a work will be very useful to those who want to go to the bottom of natural history; it is an interesting study too, to notice the modification in form, the degradations, substitutions, etc., among the internal organs and bones. The structure, forms and positions of teeth, too, are interesting to notice, so invariably are they the index of the economy and the position in nature of the animal."

From this year dates the first of his communications to Scientific Societies (The Academy of Natural Sciences of Philadelphia).

1859.

1. 1. Pr. A. N. S. 1859. p. 122 "On the primary division of the Salamandridæ" (6 pp.)

From Londongrove, Sept. 16, 1860, he writes to his father:

"I have been wanting for a long time to attend the lectures on anatomy at the University some winter when the opportunity should offer." * * "The whole ground is gone over in a winter and the knowledge of human and comparative anatomy would be of immense service to one desiring knowledge of the proper manner of treating stock, and of general comparative zoology. I am familiar with the main points of anatomical structure and could perfect myself in the minutiæ in a winter better than students whose attention has to be directed to the main points." * * "In a few leisure moments this summer I have been tinkering at the enumeration and description of the reptiles of the North Pacific Exploring Expedition prepared in a very imperfect way by Dr. E. Hallowell."

"A few days ago I went at it and completed it before we went to cutting corn, so that it is now ready for printing." * * "The arrangement was very bad, and some old species described as new."

The preceding letters carry us over the period of boyhood and early adolescence. The next ushers in his career as a man and an original thinker, with a consciousness of his own present and prospective value to the world. In the meantime he had attended lectures from Dr. Leidy in the University. It is dated Washington, Jan. 23, 1861, and is addressed to his father, "Horatio" (Dr. Horatio Wood) and he had gone there on Monday, and after some changes in their place of abode had finally located themselves on the "sixpenny side of Pennsylvania avenue near 6th st." at $25 per month.

He published in 1860 six papers through the A. N. S., and one through the Smithsonian Institution.

He was proposed for membership in the Academy of Natural Sciences by Wm. S. Vaux, J. D. Sergeant and John Cassin, and was elected on July 30, 1861.

Washington, Feb. 1, 1861. "I have come to the conclusion that Washington is decidedly a second-rate place. Though there are two professors and a doctor in the boarding house, they are all unsatisfactory trifling people." * * "Two fairer men than Profs. Henry and Baird are, however, hard to find. Theodore Gill, a native of New York, with whom I have been acquainted for a considerable length of time, is an honorable and sincere young man, so far as I know him, though by education different enough from myself."

His contributions to science for 1861 were nine papers through the A. N. S.

Jan. 7th, 1862, Smithsonian Institution. "Gill, Kennicott and Meek are the working students in the building at present. The last is a paleontologist among invertebrata." * * "Prof. Henry came in not long ago and introduced me to Prof. Arnold Guyot, author of 'Earth and Man.' He is a small, kind looking man and betrays his French origin in his speech. We had very interesting arguments with him on zoological districts, and their geological relations. We then came to the classification of Mammalia, especially that proposed recently by Prof. Dana—viz.: That making four divisions of mammalia. Archonta (man), Megasthenes, Microsthenes, and the Implacartialia, which I found had first occurred to Prof. Guyot. It has seemed to me fanciful, and I found he could not support it with anatomical demonstration. Gill was of the same opinion that I was. Nor could he demonstrate any anatomical ground for the great separation of man. So I had a long argument, as I have often hoped to, with one of the

Agassizian school, relative to the propriety of interpreting a system of material structures, by any exhibitions of a spirit which is but temporarily attached to one such, and whose powers are obviously limited for the purpose of adapting it to its material prison and surroundings."

"His theology seemed to be truer (me judice!!) than any I have heard from a scientific man for some time—but he believed in the resurrection of the body!! Prof. Henry joined in and argued very interestingly. He has no German transcendentalism in him as it comes natural for a Friend to have. But how few of these reasoners upon the Cosmos have laid a good foundation in comparative anatomy and embryology. If acquirement in this respect was more equal there would perhaps be less difference of opinion among such men."

Speaking of his good health he says to his father: "This I owe to thy care, and with it everything that makes life pleasant to me."

His scientific work for 1862 comprised thirteen papers through the A. N. S.

The next letter, also to this father, is dated Munich, June 13, 1863, during his first European voyage. He speaks of having spent three weeks in Leyden with Prof. Schlegel, a man of wide range of ability who "knows all there is to know, except anatomy, physiology and medicine, wherein lies his great defect." The following is interesting as giving the views of so eminent a Friend on the question of maintaining an army:

"I hear nothing but bad news from the United States. It is plain that we cannot carry on those works, or achieve the results which require the united systematic efforts of a whole people without a strong government which shall absolutely rule; but it is plain also that such arrangements, as far as I can see here, are the moral ruin and intellectual degradation of a great many people; hence the conclusion that the results to be obtained are not worth the loss incurred in obtaining them; hence the request of the Jews for a king instead of a judge, was a mistake. But as things are, I suppose we shall have a strong government; what my duty would be in case I were drafted, I am as much in the dark about as ever. It seems wrong to withdraw myself from any participation in government at all—yet if one begins it is hard to stop short of armies."

During the year 1863 four papers were published through A. N. S., one through the Am. J. S. and Art, and one through the Zool. Soc., London.

From Albany, Aug. 14, 1864, he wrote his father that he

was detained over Sunday with his friend, Andrew Longacre, a Methodist minister, from inability to reach the Catskills after a visit to Howe's cave, 3 or 4 miles west of Schoharie. He mentions having attended a small Friends' meeting "just possibly Hicksite" in which an aged Friend in his shirt sleeves spoke in a very comforting manner.

In this year appeared five scientific papers.

During 1864 he received the appointment of professor of natural science at Haverford college. The following year (1865), he married Anne Pim, daughter of Richard Pim, of Chester county, a distant cousin, and took up his residence during the three years of his professorship near Haverford college.

He was elected a curator of the Academy of Natural Sciences in December of this year (1865), and served until December, 1873.

His scientific publications for 1865 were ten in number.

In a letter from Haverford, March 29, 1866, he notes that in spare times he is writing an account of the structure, species and distribution of the tailless batrachians which will be published before long by the Smithsonian Institution. "It will cover about 500 species. As soon as it is finished I want to get to work at a manual of comparative zoology to use in my class." * * *

June 16, 1866. From the same place he mentions having procured a femur of Hadrosaurus foulkii from West Jersey.

His scientific publications for 1866 were eleven in number.

March 26, 1867, he writes from Cambridge. where he is the guest of Prof. Louis Agassiz, who put at Cope's service his enormous Brazilian collections. The writer was going over the East Indian, Australian and African series and proposed to bring back many specimens with him—chiefly of batrachians, of which he wrote the larger part of a complete monograph last winter. (Journal of the Acad.) "The reptiles bear a small proportion to the fishes which embrace 1300 new and all the previously known (700) species."

July 20, 1867, from Yellow Sulphur springs (Montgomery Co., Va.), where he was sojourning temporarily with his wife and young daughter, he writes that Dr. Leidy having experienced an attack of lumbago, and been ill of the limestone

water, had gone north with his wife and niece. The writer had explored six caves, one, Hoge's, of great size.

"In general the flora and fauna are very rich here, especially the entomology, which strikes one soon." * * "The forest presents a fine variety here. Thuja grows by the side of Magnolia and Andromeda arbores and the Paw-paw." * * "From the New River Sulphur Springs, Giles county, Va., July 28, '67. The trip of 22 miles down the Kanawha, from the central depot, is graphically described, especially the shooting of the rapids in a keel boat 30 feet long under the guidance of the colored skipper and crew. His young wife and child were delighted." To-day we pass quietly with a quiet hour at most in the morning; the latter with favor I have found not seldom—quite as well as in our larger assembly. Some of the dealings of the Lord with Asa, King of Judah, as well as those of Christ with the widow and her son, and the woman that was a sinner were livingly clear and encouraging as I read them this morning.

"Dear father, some time ago I made in a letter some spontaneous observations on the advantages of converse on religious subjects. This thee calls in thy reply 'a hint.' It was not intended as such. In thy last letter thee finds a want of patience, tenderness, etc., foolishness attributed and the like. Now, all this is a mistake, and as it will create difference and discomfort should be corrected. I am not the person to treat lightly any persons' conscientious scruples, even in case I do not sympathize with them, but in this case I did sympathize and have not let in impatience at any time." * * "The botany of that ridge" (on the south side of Giles county) "was curious to me: a bush Clematis; C. ochroleuca—a vine Asclepias—Conolobus sp. and the Spergularia rubra with red and green flowers, also Kuhnia—were all new to my list".

Alexandria, Oct. 27, '67, he explains that he had accepted the invitation of a Marylander to examine the Eocene and Miocene beds in the southern part of the state between the Potomac and the Patuxent, and also to procure a collection of fossil vertebrates and mollusks.

"I omitted to mention that among the cetaceans is one of the most singular known—though to myself only—as it is new, species, genus and family. It is a dolphin with a long cylindrical muzzle of much length, like the horn of the Narwhal, but not a tooth, but of the structure of the swordfish. The under jaw was short and teeth in the upper no farther than opposite to the symphysis."

His scientific publications for 1867 were thirteen in number.

In 1863 he had taken up his residence in Haddonfield, New

Jersey, six miles southeast of Camden, where he continued to live for many years. On Jan. 28, he was elected corresponding secretary of the Academy of Natural Sciences and served until Dec. 24, 1876, when he was succeeded by Dr. Geo. H. Horn.

In a letter from Pemberton, Burl. Co. N. J., March 17, 1868, he says that he had an excursion through the marl country this season.

"My friend, Prof. Marsh, of Yale College, had, however, planned to go a little earlier, so I accompanied him. We have been off a little over a week and have had good success altogether, though the weather has been very bad. * * * Prof. Marsh has studied and traveled in Europė for three years, and is very familiar with their invertebrate fossils. We have procured three new species of Saurians, apparently of known genera; one a Mosasaurus, one a Gavial, and one of large size is very near the Cetacea. It must be referred for the present to a genus named by Leidy Brimosaurus, of which a species from Arkansas, is slightly known. It is very large and has measured 35 feet at least. But it is not altogether certain that Brimosaurus may not be some strange Cetacean."

Haddonfield, N. J., March 22, '68. "I may not be out of place in taking another stay among the mountains south, next summer. I think it will not be best for me to work much in the study there, and as it is best to be a whole man at one thing at a time I would think rather to explore nature, than spend the time at farming. My near objects in the former are two. 1st., to get at the principles of development and progress of animals (including man) by a thorough demonstration of the same in some one group; 2nd, to get out a manual of compar.—anatomy for school and college use."

Pleasant Garden, McDowell Co., N. Ca., Oct. 14, 1869. * * * "I found in Henderson a long erect tubular Sarracenia which was always full of insects of many kinds, also rare salamanders," etc. * * "I took thick clothing, gum blankets, etc., and rode on a mule along the French Broad river to the Swanonoa river. Then up this beautiful stream 12 miles to the North Fork, which rises in the Black range, and flows between two high chains—the Craggy on the west and the Blue ridge on the east. Both of these rise to points higher than Mt. Washington." * * "We passed round the bases of Mt. Gibbs and the Sugarloaf to the top of the highest peak, Mt. Clingman. The views from the peaks are magnificent and no doubt the most picturesque in eastern North America. One sees 1-200 miles of the Cumberland with the great valley at their feet, and the lowlands along the Catawba river, in South Carolina. There are 25 peaks in sight higher than Mt. Washington; the near ones of the Black, Craggy and Blue Ridge ranges present the most picturesque variety, but the Great Smoky on the border of Tennessee keeps its back up for a long distance (70 miles) to within 60 feet of the Clingman's peak, (the latter is

6,710 feet above tide water). It is a great background to the many ranges east of it, and rises like a wall from the Tennessee valley. Mitchell's grave is on one of the knobs which compose the summit of Mt. Clingman; at the foot of the other is a cave beneath overhanging rocks; also a log shanty in which I spent the night with the guide. The mule went into the back room which had neither roof nor floor, and while the guide cut wood, I carpentered, trying to stop the gaps between the logs. I nailed up my saddle blanket for protection, and laid down my gum blanket for a bed; for bed clothes I put on my overcoat and covered up with a shawl. We had a great fire, of wood of Abies balsamea (which covers these mountains) and so prepared for the night. Clouds and fog soon covered us, and then the rain began and soaked everything, till after morning light. When I stepped out, we were on an island, with an ocean of white clouds around and at our feet. We ate our breakfast of cold corn bread and chicken and commenced our march through the wet bush for Mitchell's peak. My gum blanket kept me dry and by the time we ascended the peak, the clouds broke and I had a wonderful view of the opening of the valleys, and the looming up of the peaks, which appeared first as black islands in an ocean of snow. When we started on the descent all were clear except the lower ones near the course of the French Broad river which lay under an immovable mass of white clouds, whose upper surface looked like that of a vast glacier. On the mountain I found several interesting insects, salamanders, and at its base, fishes. Soon after my return we came here, a day's stage ride from Asheville." * * * * Soon after starting on the descent, a babbling brook disclosed the head waters of the Catawba, a stream, the fish, and other fauna of which I have had great curiosity to examine. This place has furnished me a pretty good opportunity. I have found already 25 species of which 6-7 are new. * *"

During 1868 were published twenty-six scientific papers.

"Raleigh, North Carolina, Dec. 11, 1869 * * I spent four weeks east of this city investigating the marl region, and collecting its fossils. This region is mostly Miocene, and the formation is more largely developed here than in any part of the United States, excepting perhaps Nebraska. It is covered with a great deal of fine forest. The most striking species is the turpentine pine. * * I had pretty good success in my fossil collecting, and with more knowledge of the country could have done much better. I will however be able to make some valuable additions to palæontology, and will have all the vertebrate fossils obtained by the state survey, to determine. The majority of mammalia are cetaceans, I have at least 15 species of these.

In 1869 were published twenty-five scientific papers.

During 1870 thirty-nine scientific papers appeared.

"Haddonfield, N. J., March 20, 1871 * * * "I was at Phœnixville recently and found many fine additions. Besides more reptiles and

insects, several rodents had been found, among them a new species of porcupine (Erethizon cloacinus), and an astragalus of very large species, almost equal to the Anguilla rodents. Perhaps it is Castoroides. The sloths are much the most numerous; there are at least twelve individuals, and two species of Megalonyx, which seem to be both different from the known M. Jeffersonii." * *

"Haddonfield, N. J., April 30, 1871. "* * * I have on my own part found the only spiritual rewards to be granted to industry in a cause designed to be of ultimate benefit to mankind. Though there are callings of apparently more real use than mine into which I would have been willing to be led, and though it takes a great deal of such work as mine to produce much result, yet I am as well adapted to it as any, and have the means of prosecuting it more conveniently than most. In thy last thee speaks of the theory of development being calculated to do incalculable mischief in disturbing faith, etc. This thee would not say, I suppose, if thee thought the doctrine true. If thee can place thyself in the position of one who believes it to be true, thee would see in it an aid to the cause in which thee is most interested. viz: a shaker of false faiths, and an aid to that which is founded on a rock, "that which cannot be shaken may remain." If it aid, in reducing religion down to a personal thing, a matter of the heart and not of the head, it will do more for it than any one worldly thing has done for a long time. And this is one of the missions of science, to mark precisely the limits of knowledge by the understanding, and the boundaries of that realm of knowledge by spiritual discernment alone."

* * "I have been studying the fish skeletons, and am fast building up an analytic system, which will straighten some things up. The opportunity is fine." * * "MacNeil has sent some very valuable things latterly." * * "The Phoenixville cave awaits the beginning of excavations." * * "I am temporarily at work on a collection of fishes from the Ambyiacu river in East Equador. I find nearly 100 species and have gone only over the catfish (Siluroids) and find 22 species. Among these are 6 new genera and many more new species. Two of the former remind one of iron-clad gun boats and have immense swim-bladders to float their armament."

Topeka, Kan., September 7, 1871.

"My dear Sister: I have some time this morning, and think perhaps thee and Philip would be refreshed by a little breeze from the prairies. This town is on a rise of ground and overlooks in some directions, the most interminable prairies. I never saw these land-oceans before, and truly they are worth a trip out here to see.

"The flowers we have often heard of, but I did not suppose they were so tall; as high as a man's head or a steer's back. Sunflowers, goldenrods, and various Compositæ, flax, sage, Euphorbia, endless Verbenas, etc., etc., cover the great expanse in every direction. The air is delightful, and it is impossible not to be taken with the spirit of push of the far west. The plains are said to be alive with buffalo, so much as to stop the trains on the 'K. P.'"

In 1871 he published thirty-seven scientific papers.

"Haddonfield, N. J., May 24, 1872." * * I am now busily cleaning off work for a departure and absence from home. * * I suppose we will leave for the west on or near the 14th of next month. * *

"I have attained some little light as to what constitutes a motion to speak and what not; a thing, however, on which there will no doubt always be something to learn. It is very repugnant to me to appear in public, but that feeling grows much less as I find material furnished and way open to declare in different ways something from the heavenly treasury. The feeling of willingness also removes the last hill of difficulty, so far as intention goes. Going away would seem to interfere with this, but I feel willing to go, as the opportunities are remarkably good, and health is as necessary to one work as the other. There is nothing in the way, and I may possibly find something to do beyond my scientific work." * *

Camp near Church Buttes Wy., July 28. 1872.

"Dear Brother * * I am now two weeks 'on the trail', but expect to reach Bryan to-morrow so as to mail some letters. I had to wait three weeks at Ft. Bridger before I could get an outfit, and improved the time to make various excursions. I have no escort and don't need one in this country, of which I am heartily glad.

"We are still in the well watered region of the heads of Harris fork of Green river. Our course commenced on Smith's fork, then crossed to Cottonwood creek, and then down the creek to Smith's fork again. We are now on Black's fork below where Smith's fork enters it. To-morrow we cross it and take up the route for Green River city (!) (a dozen houses) via Bryan, then we strike Bitter creek and follow it east into a howling wilderness, where water is scarce and bad, and grizzly bear plenty. So far we have been quite successful in the fossil line. I have 20 sp. mammals (8 new) 20 do, reptiles, 12 new; and 5 sp. fishes. The labor of getting them out is considerable as the rock is hard. We use chisels, wedges, and stone hammers. This is a land of mosquitoes and midges or gnats."

Camp on Green river at mouth of Fontanelle creek, Sept. 8, 1872.

"Dear Father * * The present point is 50 miles west of the U. P. R. R. and at a considerably greater elevation."

"The Bitter Creek region is a remarkable one for large vertebrate fossils, as the Bridger region is for small ones. I obtained ten or more new mammals and several fishes and reptiles, besides various old ones. The larger ones were a new species of Palæosyops (near Palæotherium), the largest of the species; a new genus Metalophodon related to another new form I call Eobasileus. There were remains of 3 species of the last, and over 13 individuals. Six I found entombed near together. I found two skulls, one nearly perfect of the species I call E. cornutus. * * * In a word Eobasileus is the most extraordinary fossil mammal found in N. America, and I have good mate-

rial for illustrating it, Marsh and Leidy have obtained it near the same time and I have no idea whether they have fathered it in advance of me or not."

"Since coming up here I have had good success. I found 30 species, several of them new. I found a genus as remarkable for minuteness as Eobasileus is for bigness; what appears to be a hoofed or hog-like mammal about as large as a red-squirrel! But its teeth are wonderfully monkeylike, so I call it Pithecodon. The number and form of teeth are just as in some monkeys."

"I have found a Rhus, like or same as R. aromatica and have seeds for thee; also of a very fine currant and two kinds of Cornus, one with large drupes like C. mascula, but with large leaves like Elæagnus. Also some other seeds." * *

He was at this time attacked by an illness to which he referred later.

Fort Bridger, October 12, 1872. * * "I am now so far convalescent as to be able to write to thee and some other friends with my own hand."

"* * I am favored with a good appetite, and my nights are positively happy under the influence of an opiate, even if I can't help mashing a carbuncle or so.

"I am also blessed with cheerful feelings, and sometimes still more so by the nearness of the Church's Comforter, the Elder Brother, and sympathizing Friend, whose service is perfect liberty; and who sticks close to those that endeavor to walk near to him. The little service that I had among my men and others whom we met when I was out, has been blessed to me, and not lost on some of them; at the present, I do not like to speak of these things except to such as thyself and also for the purpose of resting the thoughts briefly upon the subject, amid so many outward occupations." * * *

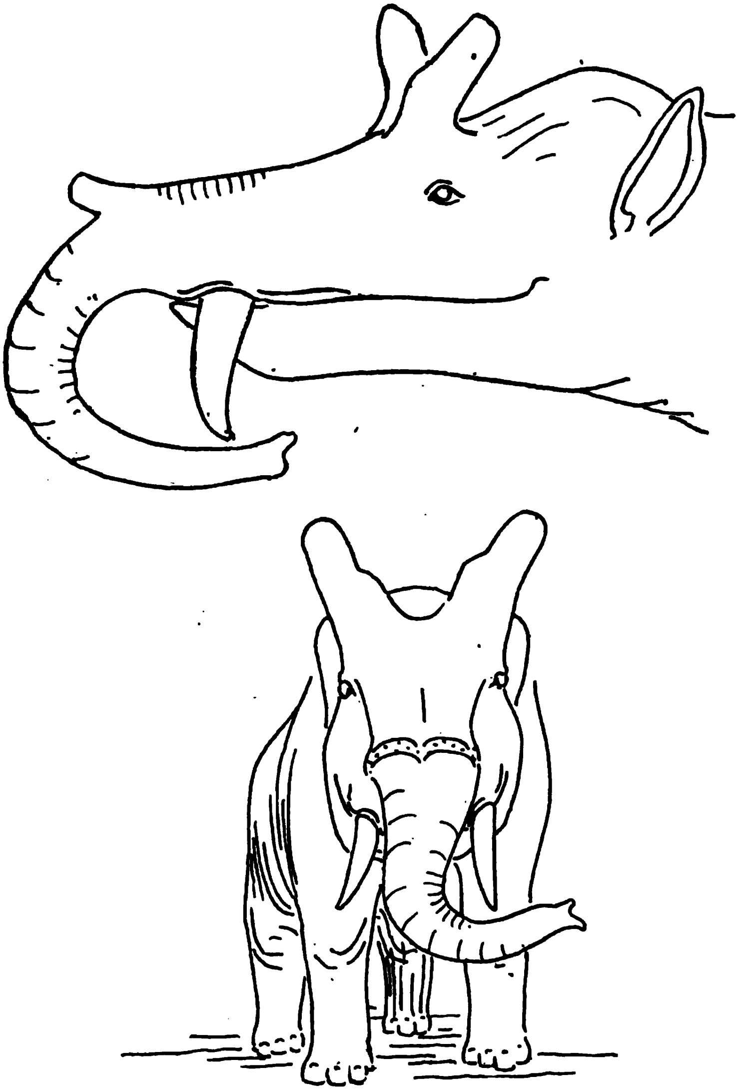
"I have sketched a complete outline of a handbook of zoology and palæontology for the use of students which will only require time to fill up. It is designed to be very brief and comprehensive. I must get it out, after my report on the Eocene mammals is concluded."

"My head is now delightfully clear. During my fever I had horrible visions and dreams, all speaking ill of something, and frustrating my attempts to sleep. I had many other nervous states, all of which caused great suffering. This is now nearly two weeks past."

"I often thought of mother as I lay sick, and believe I should now better appreciate her trials and sufferings." * *

"I found in my sixty-five day's exploration the remains of species of animals according to the following figures: species, quadrupeds, 32; birds, 2; crocodiles, 6; lizards, 4; snakes, 1; turtles, 17; total, 62; and 13-14 kinds of fishes.

About fifty of these were not in the books, and I publish their characters with a name for each. Some of them were of the hugest size,



Figures 8 and 9.

while others are not greater than mice. Not one of them is living yet and nothing like a great many of them has ever been seen by human eyes."

In 1872 he published fifty-six scientific papers.

Haddonfield, January 12, 1873. * * "I had promised two articles for an atlas and cyclopædia each, last spring, and had to finish them post-haste, before getting at my Wyoming fossils."

"The first brought $100, the second about $200. The latter is a monograph of comparative anatomy and with that for the atlas (on geographical distribution) will form two important sections of my book in which I made so much "progress" when convalescent at Fort Bridger. The Eobasileus is the first fossil I have given especial attention to. Prof. Marsh wants to consider its related forms as indicative of a new order of mammalia, but more study convinces me that they are Proboscidians in almost every respect, only differing in physiognomy greatly. They had a proboscis I am now quite sure, and walked with the knee far below the body as elephants do. Their looks would be thus (Fig. 8). A form different enough from elephants generally, but reminding one more of the hog. If the front were filled up by the enormous air chambers of the elephant, the aspect would be greatly changed, without altering the true affinities equally. The front view is especially strange. (The horns and head are rather too large in this drawing.)" (Fig. 9). (Plate XV).

Haddonfield, Feb. 5, 1873. Speaking of a dinner given to Prof. Tyndale he says "It was a good assembly of 500, mostly naturalists, and though the dinner was good, there was more reason and soul and no conviviality in the usual sense; Evarts the lawyer presided and Tyndale, Draper, Barnard, etc., spoke for science, and Beecher and Dr. Bellows for theology. The whole subject was well handled and I was particularly pleased with Beecher, whose acquaintance I afterwards made. Bellows was not afraid of his audience and told them plain gospel. He told Tyndale, that on his departure he should have as many of his prayers as he would believe in, and alluded generally to prayer in a very effective and graceful manner. Tyndale in his remarks spoke largely of a sense of duty, which he considered important, etc."

Washington, D. C., March 16, 1873 * * "Some one has just endowed a chair of natural history at Princeton college to be called the Henry chair, and Prof. H. recommended me to Prof. McCosh to fill it. The latter objected to my evolution sentiments, for those views are much condemned at Princeton. I have not much intention of fixing myself there, as the hours and work generally will probably require too much time, but I may find the University of Pennsylvania better, especially as it is nearer home. One or the other I will probably undertake."

"It seems very hard for some to accept any evidence except that of the senses, and having no other, they deny supernaturalism and even class it with delusions. It is hard to reason with such men, especially

if they be tolerably moral, though they very seldom are even approximately so."

Haddonfield, April 9, 1873 * * "I am in a bad fix in one respect. The four plates thee has seen (in 800) of Loxo cornutus were to have been published by the Philos. Soc. but the delay in getting permission to print them was so great that when the permission came I had them out. I would not wait on account of ———'s criticisms. I also learned that the lithographer charged $30.00 apiece, so large a sum that the secretaries withdrew permission and said I must ask the society. I did so, and some one to whom I had given copies of the paper (Dr. ———) asserted that they had been already published. ——— and others of that stamp then said it was irregular and they threw the whole thing out. I now have to pay the bill for drawing and printing the societies (series ?) of 1,000 copies which is about. for drawing, $120; printing 1,000 at 1.25 p. 100 (each), $50.00; and finally for printing 2,350 copies for my reply in the American Naturalist, $120.00; total, $290.00" * *

Haddonfield, May 26, 1873 * * "I write briefly to say that the U. S. Geolog. Survey has taken the six plates" * * "after much delay, but I have to pay for printing an edition of 3,325 copies for Am. Naturalist and self, which cost some $80.00."

Greeley, Col., August 6, 1873 * * "I have had great success since I wrote from Pine Bluffs, having at last reached the strata which contain most of the fossils. I have at least 70 species of Vertebrata, all Mammalia except five. I have explored two horizons, the lower and the richer containing 50 of the species. It is largely a new fauna also, and quite distinct from those of Nebraska or Wyoming. I have some 15 odd-toed hoofed (Perissodactyla), 10 Carnivora, 13 Rodents, 3 Insectivora, but no Proboscidia as yet. It will form a division of the Miocene period.

"The most remarkable of the forms are the species of huge Perissodactyla with horns; which I have found, and which correspond largely with the horned proboscidians I found in Wyoming in respect to the position of the horns. Thus one has rudimental horns, one on each side of the nose; another, prodigiously long horns in the same singular position; a third, very large horns right over the eyes as in Loxolophodon coruntum! They are, however, but little related to the latter, but are not very far removed from the Rhinoceros and Palæotherium. I named the species in the order mentioned, Megaceratops heloceras; M. acer, and Miobasileus ophryæ. The skulls are about 3 feet in length." "I found some hundreds of jaws of rodents with a good many perfect crania."

"Pine Bluffs, Wy., U. P. R.R., August 13, 1873. * * Mammalian bones are very abundant in some places and I obtained 18-20 species very soon. One of the novelties is a weasel-like carnivore; another a large species of Rhinoceros with deficient dentition as to numbers, but greatly increased as to size of teeth. I call it Aphelops megalodus. The species of camels and horses are most numerous."

"My health is greatly improved and I have the ravenous appetite the plains always produce. Wild horses are not scarce; we have seen them three times. Indians peaceable with the whites, but the Arapahoes and Utes are at war, and for an exception the latter have been successful.

"To-morrow I go to Evanston. At this place there is a great puzzle as to the limits of the Cretaceous and Tertiary formations. Indeed this whole country seems to furnish closer connections between the two than any other; hence there are differences of opinion as to the boundary line. Last summer I made some important progress in proving that what many called Tertiary was really Cretaceous. If you do a good thing it is either not true or done long before! Progress is only made in spite of annoyances from parasties and jackals; but it is a good discipline to learn to bear with them, as our great Example did with the Jews. However He denounced them sometimes." * *

Pueblo, Col., September 23, 1873.

"Dear Brother: Yesterday I had secured 103 species of which a large p. c. are new (at least 75). It is in fact a great new fauna, whose position is probably intermediate in time between the Bridger and Nebraska groups.

"First day December 14, 1873. "Dear Father. Thine of sixth day is at hand, and I report progress. On reading it I wrote at once to Gilbert Cope, giving my views of immortality on a materialistic basis, as the one on which he probably reposes his disbelief in it. I can see no possible reason for rejecting it in the most advanced materialism, so called; although it may be in large measure unknown, I do not believe that it will always remain so; or that it is unknowable.

"As to the learned professor of 'Copeology,' I will correct his errors when they come in my way, as is the custom of naturalists; and I expect the same treatment. This need not and should not excite any personal feelings in any person normally or properly constructed; unfortunately—is not. Unfortunately I say, because he makes many errors. and is so deficient, that he will always be liable to excitement and tribulation. I suspect that a hospital will yet receive him."

The following is probably the letter referred to in the last communication.

Haddonfield, N. J., December 13, 1873.

"My dear Cousin * * The question of immortality interests me as I look on it from the evolutionist's standpoint, and to thee it must have more than a speculative interest as thee nears its confines. To all of us it is a subject very difficult to obtain any light upon, as the present state of human knowledge offers few tangible points upon which we can seize in order to commence investigations. To suppose on this account that there is no such thing as the future life appears to me to be a non sequitur, and as unphilosophical as to have denied the possibility of the science of molecular physics, as might have been done twenty years ago. How often have I heard persons say that we

should never know the law of the creation of man, of the nature of life, mind, etc., yet these things are to-day measurably cleared up. So with the life out of the brain (or body, as people say). If I thought I could in obedience to sound reason deny a future state, I think I would be willing to do so; but as it is, I think denial of it is without sufficient basis of evidence (it only claims the negative kind) and is not a proposition that would be accepted by the scientific world as proven.

Analogy is all the other way. The force which pushed the lower forms cf life forward in their developmental progress, was not disappointed of its results. Many fell by the way, i. e. the unfit, and many have remained to occupy subordinate places in the last (existing) economy of nature. But one of the lines realized the highest power, i. e. brain power, by which the species (man) which possesses it, rules the creation with the fewest advantages of bodily strength and material weapons. While all other lines maintained themselves by the perfection of their instruments of offence, defence, and physical gratification, the one which led to man, the quadrumanous, was cultivating the higher faculties of intelligence.

I cannot but believe that the same will be the result in the department of mind. Each of the faculties might be regarded as a mental species. Some are unfit, and will be extinguished by the workings of the social systems; others are fit and will be persistent. The highest of these is exact justice to others, or the "love to the neighbor." * * *

"I strongly suspect that a material docrine of the future state will be more or less understood at some future time. Mental physiology even renders it probable. It is evident that there is not only a development of force (by conversion) in the production of the highest kind of mental function; but of the arrangement of atoms of matter also, and why this matter might not persist in other relations than those it finds in the human brain I cannot see. The vegetable makes protoplasm out of inorganic substance, and the animal makes the varieties of protoplasm which converts force into many others, as heat, motion, and the various kinds of thought. Why a third change of matter should not occur, a kind being produced to which the boundaries of the body should not be necessary, I cannot perceive; such matter would, of course, have its own peculiarities as a force converter, like any other substance. This is far in the region of speculation, and many would regard it as wild, but hypothesis is always the first step towards knowledge. So I dare not deny a future life, and as we all probably wish it, in case it should be happy, we may seek for phenomena which indicate the existence of such a state of happiness in the human mind in this world. * * * If we believe in a development into a future life, we must believe that as many have gone before us, that future state must be well populated. If this be true I see no difficulty in supporting that communication, and hence prayer is a reasonable thing." * * *

In 1873 he published thirty-four scientific papers.

Haddonfield, N. J., January 31, 1874. Dear Father * * "I sum up in the new Bulletin the results of my (?) study of the relations of the study of the Cretaceous and Tertiary formations in their points of contact. The result is that the beds generally pass from one to the other, but there is an interruption in the history of life. But for animals and plants the period of interruption is not the same; the Tertiary plants were introduced long before the Tertiary animals. So there could have been no such great destruction after all, and it goes to prove that change took place in both cases by migration, not re-creation."

Haddonfield, N. J., March 29, 1874. Dear Father * * "I recently went over the reptiles and fishes of Wheeler's survey with interesting results. I found one new group of fishes pertaining exclusively to the waters of the Western Colorado—the only one peculiar; all the rest are usual forms of the east.

Philadelphia, July 7, 1874. Dear Father. "I have just returned from Washington, where I have concluded a contract with G. M. Wheeler, of the topographical engineers, and director of the Geological survey of the territories west of the 100th meridian. By this I engage to work on the geology and palæontology of the region he surveys, until the work is concluded (about a year) at the rate of $2.500 per annum, and $30 per month additional for provisions when in the field, and all expenses of expedition paid."

Summit of Sangre de Christo Pass, July 29, 1874.

Taos, New Mexico, August 6, 1874. Dear Wife * * "We have now been out twelve days from Pueblo, and have landed in a new and peculiar country. * * The valley of Taos is the finest we have seen. Four streams of beautiful water flow from the mountains and unite to form the Rio de Taos. There are seven villages on these, mostly one to three miles apart which altogether contain some 6,000 persons, I am told. This is to an American of 'the states' a foreign country."

San Ildefonso, N. M., August 15, 1874. Dear Wife * * "The pass of the Rio Grande through the Picoris Mtns. presents very grand scenery, embracing prodigious precipices of granite, or in some places basalt, which was poured out from some ancient vent. As soon as we come to the Picoris river which comes in from the east, the Pliocene 'bad lands' appear, with great towers and buttresses and walls, all wearing away by the weather. * * Next day we rode through Embuda and forded the Rio Grande at that point, having left a note for the doctor and party to move out to San Juan 18 miles south. We struck for Abiqu 40 miles w. on the Chama R. * * * The first day we passed over a bad land country and reach Ojo Caliente, a few mud houses round a very large hot spring which flows into a fine creek. Next day to Rito, a small place in a beautiful valley with a creek, the Rio del Rito. * * Some of the specimens I saw, and they were nothing more nor less than my old Bathmodon of Wyom-

ing. I could not have desired anything more agreeable nor surprising than this discovery of our lowest Eocene 500 miles south of where now known! and in full confirmation of my theory published last winter that the fauna of Fort Bridger beds came from the south! Thee need not mention this for a while, for reasons which I will presently mention." * * "The party had to wait at San Juan (which is an Indian Pueblo town), so Mr. Shedd and myself left for an exploration of the bad lands on the w. side of the Rio Grande, opposite San Ildefonso, and of the Jemez mountains. This we did, camping two nights, once in the pine forest on the foot hills of the mountains. We climbed the first range, say 9,000 ft. high, and had a most glorious view of the valley of the Rio Grande, with its bad lands, and the Rocky mountains on the east, rising 1,000 ft. We found fossils, Mastodon. Rhinoceros, camel, Merychyus, and a fine vulture. Yesterday Mr. Yarrow and self fished in the lagoons of the Rio Grande and caught ten species, many new, and two new genera."

"Santa Fe, August 29, 1874. Dear Father" * * "For over a week we have been investigating the bad lands near San Ildefonso, and only find them moderately rich in fossils of Pliocene age. We have some 25 species of Vertebrata, including three dogs, a weasel. a mouse, a beaver, and a gopher; two horses, a rhinoceros, one or two species of Mastodon, three camels, and three species of Cosoryx, a genus intermediate between antelope and deer. The origin of the curious phenomenon of the shedding of their horns and redevelopment periodically by the deer has always been a puzzle to evolutionists, but these curious ruminants, I think, furnish the clew. I have some twenty-two specimens, mostly the horns of only one side, and about half of these have a burr at the base like a deer, and the other half are solid and smooth. I find that those with burrs have all been broken, and reunited or "ankylosed." Some of the antlers (the horns of 2 sp. are branched), also produce a burr where broken. I believe deer descended from permanently horned ruminants, which frequently broke their horns in fighting in the spring rutting season, and that the effort to repair the break became periodical, and growth was thus directed to this region.

This is a very peculiar country. The valley of the Rio Grande varies in consequence of three conditions. First, where the great surface bed of basalt is unbroken, it is level and barren, with grass and brush, and the surface is level, the river running in a deep cañon; second, where this bed is broken up, the underlying pliocene soft sand leaves the country in dry sand hills, with scattered cedars; or, third, where there is water, in grassy and rich valleys among the foot hills of the mountains. Such a valley contains Placita. It is a beautiful place, and displays rocks of four periods, in the latest of which I found remains of Elephas primigenius. The bed is thus postpliocene, and not the pliocene I looked for. There are but few species of trees, only pine, cedar, and cotton wood, but flowering plants with large arrow-shaped leaves run over the ground and various species of

Cacti render walking an exercise of care. S. of Santa Fe I first saw a jointed globe Cactus with white flat spines and large flowers.

I am trying to learn whether these Indians have been semi-civilized by the "peace policy" of the Jesuits, or whether they are the descendants of a once civilized nation, I am not sure, but evidence favors the former view." * *

Sierra Amarilla, N. Mex., September 14, '74. "Dear Father. Our route from Santa Fe was up the Chama R. via Abiquin to this place. I then left the main party here and with one assistant and two guides, went southwest to the divide between the tributaries of the Chama and San Juan rivers, for the purpose of finding the Eocene lake bed, which I supposed to exist there. In my Bullet. No. 2 of Hayden (conclusion), I stated that the fauna of Wyoming probably came from the south. I succeeded in finding the beds, and plenty of remains of fauna; in five days, forty-three species of Vertebrata. The basin is 500 miles south of the Wyoming one, and the horizon is the very lowest Eocene known, rests on older Cretaceous rock than those of Wyoming. The situation thus fulfills my expectations exactly, and it now remains to work it up carefully. I already have some nice and interesting forms." * * "One of us, R. P. Ainsworth, topographer, was accidentally killed by the discharge of his revolver a short time after I left camp on my southwest exploration."

"Eocene Lake Formation, New Mexico, September 15, 1874. We got as far as this point far up the Rio Chama, when I had to divert the route from that laid down in the official instructions from W—, in order to make the discovery I expected. * * We traveled through a beautiful and mountainous country southwest, finally reaching Gallinas creek and following it along the northwestern base of Gallinas mountain till we reached the mouth of the Cañon des Heguas, which is a gorge twenty-five miles long and in places 1,000 ft. deep. I left — — and the pack mule at a large spring at the middle of it, and pushed on with the guides to the W. end where we crossed a low ridge and looked westward far into the flat basin of San Juan, tributary of the Great Colorado. But, remarkable to relate, the entire length of the cañon I found to be excavated in a rock deposit of a fresh water lake, but the western or top ones were nothing less than the long looked for bad lands of the Eocene! My dream of several years was realized and we hunted awhile and then rode to our dark camp in the narrow cañon in high spirits. Guide No. 2, José by name, and self rode to some bad lands in another direction south, I had seen not long before, and reached there at about twenty-five miles from camp. I was delighted to find them Eocene again, of the character of those at Evanston, Wyoming; and as soon as we picketed horses, we began to find fossil bones. The first thing was a turtle, and then Bathmodon (Cope) teeth! and then everything else rare and strange till by near sun down I had twenty species of vertebrates! all of the lowest Eocene, lower than the lowest at Ft. Bridger. The most important find in geology I ever made, and the paleontology

promises grandly. We rode most of the twenty-five miles back after dark, and our cañon was especially so. Next day we packed provisions, bedding, etc., on my mule and I walked eight miles and then mounting my guide's horse let the man walk eight more along the valleys of the Gallinas to find a new camp. * * *

I am often glad that I never carry a pistol. It is all an absurdity, even from a defensive point of view! It is one of Mr. ——'s weak points, and I think he might as well put it in his trunk now."

Camp Gallinas Cr., September 27, 1874. * * "I have over 75 species of Vertebrate fossils, many new. * * * The most remarkable are toxodonts of four species and two new genera, which I call Calamodon and Ectoganus, varying from the size of a sheep to that of a cow. The order has never been found out of South America before, and is in structure between rats and hoofed animals, especially elephants. * * * The Indians have left the country. Last night (First day), I read and prayed in camp, but the Spaniards evidently do not understand. It is our only religious exercise, but I have succeeded in getting our cook to stop swearing, and I hope he will be over the habit altogether."

"Camp N. W. from Nacimiento, New Mexico, October 11, 1874. * * * I have been at work on the bad lands, and hard work it is: much harder than last year. We go for a mile or more and do not see a fossil, and then when we find them they are badly broken. Still the results are more important than last year, owing to the antiquity of the beds. I have now some 90 species of vertebrates from this bed, six of them toxodonts. I have also discovered the deposits of another fresh water lake of much greater age, say lower Cretaceous, not many miles from here, which contains remains of saurians,—one like Laelaps I have a tooth and a vertebra. The soft bed of marl in which they occur is, if possible, redder than blood. * * * "First day, evening. We have finished our little worship, and a favored time we have had. I always feel the love of God after these services and sometimes during them. We missed last week, owing to rain. Our tents are too small for more than two persons, and outside it was too wet. To-night we sat around a fire of Piñon wood. I am now writing by its light stretched out on the ground."

"One part of a day I spent in examining a village of ruined stone buildings of the extinct race which (?) once thickly peopled this country, forming a small town which occupies a most inaccessible cliff near the Gallinas creek. It is a "hog-back" and drops off in a precipice 250 to 300 feet on one side, and slopes at an angle of 45°-55° on the other, and is naked sandstone rock. The upper edge varies from three to twelve ft. wide, and here the houses stand in a row, with various interruptions, to the number of twenty-five. The walls are of large stones, sometimes very large, 2½ ft. thick, and there remain standing sometimes 15 feet of them, generally on the side next the down hill slope."

In 1874 Cope published thirty scientific papers.

Haddonfield, N. J., August 8, 1875. Dear Father: "There are three forms of evolution doctrines: (1) That non-vital force evolves life; (2) that internal consciousness is the source of non-vital force and life; (3) that external or supernatural force, applied from without, maintains development. My studies have led me to the second position. The third is Prof. McCosh's; the first that of the materialists." * *

In 1875 Prof. Cope printed forty-five scientific papers.

"February 29, 1876. Dear F. * * In zoology the vertebrate chair is nearest equal to that of Mollusca, each representing a "branch" of the animal kingdom—while the Lower Invertebrate includes a much greater range, viz.: the branches Protozoa, Coelenterata, Echinodermata and the Worms and Crustacea from the Articulata.

In numbers Vertebrata include the fewest species of the four geological chairs, viz.: Vertebrata, 26,000; Mollusca, 35,000; insects. 400,000, and Lower Invertebrate as defined, 50,000.

P. S. In Philadelphia the students of Mollusca exceed those of Vertebrata or are about equal, while in the United States the entomologists equal in number all other kinds of zoologists together."

"Haddonfield, N. J., June 1st, 1876. Dear F.: "In the light of further reflection, it seems to me that your serious discussion of the proposition of the transfer of life from one substance to another in connection with evolution, is well worthy of a place in a scientific journal. I would add that the popular handling of it in your graphic way, as based on said discussion, would grace the pages of the Penn. Monthly." * *

"Cow Island, October 3, 1876. Dear Wife: * * Yesterday we moved out of the bad lands after procuring some good things. We had a difficult task to get down to the Missouri through the canons and precipices. Had to let wagon down with ropes. We are now camped on south side of the river four miles below here.

"On Missouri river steamer C. K. Peck, near mouth of Moreau river, Oct. 20, '76. Dear Sister: * * I was disgusted with the superstition of the officers and crew, a day or so ago. I gathered a number of skulls and skeletons of Sioux with a bag of tools buried with a chief, and brought them to the boat and boxed them up. The uproar it created among the poor white element that ran the lesser offices, scared the captain so that he ordered them all taken back to the place where I obtained them. He was greatly scared, and said I had "immolated the graves of the dead." The rumseller made the lowest protests, mingling oaths and sentimental stupidities in equal proportions. The clerk protested that no one dare touch the bones of his "little wife," which lay down in some Arkansas swamp, and the engineer declared that the Sioux would capture the boat! * * * "

His scientific publications for the year were fourteen in number.

At the close of the Centennial Exposition in Philadelphia in October, 1876, the splendid success which had crowned their labor induced the public spirited citizens of Philadelphia to put forth efforts to retain in that city a permanent monument of it. A special feature of the permanent exhibition was the Educational Department. Cope was made chief of the division of "organic material" including specimens illustrating these two branches, and the author was put in charge of the division of inorganic material, including those illustrating lithology, geology and manufactured chemicals.

Cope took the greatest interest in this project. He frequently refers to this subject in the letters of the next two or three years.

"Houston, Tex., September 12, 1877." * * I obtained a nearly complete skull at Dallas and a wonderful saurian."

"San Antonio, Tex., September 16, 1877." * * At Houston (23,-000 people), we saw the city and caught a very peculiar little toad (Enoystoma), which made the street gutters vocal with its cry. I have since heard it in San Antonio streets. * * * The weather has been hot like Philadelphia in the Centennial year. But there is a strong breeze every evening, which is most delightful, bringing sleep and comfort. It comes over the plains from the gulf, a veritable sea breeze. This is almost a part of the Mexican zoölogical region. * *"

During 1877 Cope published forty-seven scientific papers.

"Philadelphia, January 29, 1878. Dear F. * * I have instructed our publisher to add your name to the list of contributors." (To the American Naturalist.)

Dr. —— goes on also as he will furnish Swedish news." * *

"Haddonfield, N. J., April 3, 1878. Dear F. * * You now have an example of the beauties of the action of a body constituted as is the Academy—that logic does not always enter its head at the proper time. * * I abandon the lesser fight for the sake of the success of the greater. This course was illogical, doubtless, but the greater logic of a dispute is success." * *

"May 21, 1878. 2102 Pine St. Dear Wife * * Prof. Hunt is going to attend the Geological Congress in Paris and wants me to go with him. This I am much disposed to do. I think it will do me much good and I will also attend the meeting of the British Association at Dublin. On some accounts it is not convenient to go, but I must counteract the —— mud, which appears to have stuck over there in several places. I have a disposition also to go to Texas to where

—— is at work for a couple of weeks or so. There are some things I am very anxious to find out if I go to Europe, before I go, and this can only be done by a visit to the field."

"S. S. Elysia, August 12, 1878. Dear Wife * * I can beat the British Museum in the large saurians 'all hollow.' I found they had been working up the fishes of the English Chalk according to my system, and had discovered a number of new species of my genera, some from Belgium as well.

"I have made the acquaintance of various men whose names I have long been familiar with—as Boyd Dawkins, Traquair, etc. The former I have formed a great liking for. I have spread out Mr. Ryder's drawings of Camarasaurus, etc., in the loan Museum, and they have attracted great attention."

"London, August 25, 1878. * * I enjoyed the Association very much, and made many very good friends. Among these, in the order of my preference, I enumerate Prof. W. Boyd Dawkins, Leith Adams, Prof. Macalister (of Dublin), Dr. Traquair, of Edinburg—all paleontologists in the Vertebrata. Then of the geologists I was very kindly treated by John Evans, president of the geological section, and I learned to like Dr. Hicks, of Wales; Mr. Pengelly, of Cornwall. The only traces of ——'s handiwork I could discover was in an indifference of Huxley's, which I ascribed to that source. He took no pains to see me nor hear any of my papers—a coolness I suspect he would not have shown to friend ——. I, however, introduced myself and I think we should have had some pleasant conversation. * *

"Paris, September 6, 1878:—On reaching here from London I found that the French Association for the Advancement of Science was in session. I attended the meetings of the last two days, and began at once to make acquaintances. Of these, I may mention among the zoologists, Mr. Lataste of Paris, Professor Casco (Genoa), ("the Commandatore") Cappellini of Bologna; and of the geologists and paleontologists the count de Saporta (of Aix en Provence) and Professor Filhol of Toulouse. The last named is of about my age, and has discovered more remarkable species of fossil vertebrata than any other person in France for several years. * * *

"I was invited to dinner at Professor Alb. Gaudry's at 7 p. m. Professor Gaudry is professor in the Jardin des Plantes. I omitted to say that Professor Gervais, professor of zoology in the Jardin des Plantes, gave me a private dinner before. There were some 25 persons at Gaudry's to dinner, the only ladies being Madame Gaudry and Madame Hébert. I had the place of honor to the right hand of the president of the congress, with Count Saporta on my right. Every person present was noted in geology and paleontology. Profesor Hall and Professor Sterry Hunt were the other Americans present. There was also a grand entertainment or reception at the house of the minister of public instruction one evening, where the congress was entertained at the same time with nearly half of the schoolmasters of France. Here I made the acquaintance of Mr. Powel, whose name I

often write. M. Matheron of Marseilles and M. Loriol of Switzerland. The first named was once an active palæontologist; he is now a senator from Algeria, belonging to the extreme left. * * *

"Finally, a few nights ago, we had a grand banquet at the Continental Hotel, a most glorious place to be sure, on the Rue Castiglione near the Louvre palace. I sat next to Dr. Sauvage, one of the secretaries of the congress, and a youngish man, with whose writings I have long been familiar. I also met there another naturalist, like Sauvage, belonging at the Jardin des Plantes, Mr. Brocchi. Both these men had been going over my work.

"I have received lots of books and had a call from Professor Ernst Häckel of Jena, Germany. * * *

"At the last meeting of the Geological society I was nominated for membership in the Geological Society of France by Professor Gaudry, the president, and Professor Hébert, the president of the late Geological Congress, and member of the institute, the two most important members. I consider this quite an honor."

"Paris, September 29, 1878. * * My last excursion was to Reims, 180 miles in Champagne, where I went to visit a Dr. Lemoine and his collection. The collection I found very important, as it combines the faunæ of two or three formations of our western regions which are separate with us, and especially includes the beasts, etc., of the Upper Missouri region which I discovered in 1865, which have never before been found in Europe. All are from Reims! I found eight or ten of the genera which I named in 1865-6, some since then described by French authorities."

"London, December 10, 1878. * * I have seen several old friends since coming here; Prof. Owen, Dr. Güther, Mr. Seeley, and several new ones. Mr. Seeley has always been my fast friend through evil as well as good report and is so still. He is one of the ablest men in the country, and is a friend worth having. I have spent two evenings there and go again this evening and will meet another palæontologist, Mr. Hulke. * * I purchased the collections of fossils from Buenos Ayres in the Exposition. It is the only lot of the kind that has ever come to N. America, though they have been known in London, Paris, etc., for a long time. It is a splendid collection."

During 1878 Prof. Cope published forty-one scientific papers.

On March 25, 1879, he was elected a member of the Council of the Academy of Natural Sciences, (in which he had been an ex officio member during his terms as curator and corresponding secretary), and held this office till January, 1880.

"Coles Station, Cal., September 1, 1879. * * At 4 a. m. I reached the U. S. fish breeding station, on the McCloud river. * * * In the afternoon we passed the Castle Peak, a wonderful serrate crag rising naked from the surrounding hills and forest. Then we came to a wat-

ering place much resorted to, whose waters are like those of Saratoga. It is called Soda Spring. Before this a turn in the road had brought into full view Mount Shasta, one-third covered with snow. I have been enthusiastic about this glorious mountain ever since. It is the grandest thing in California. Its immense mantle of snow gives it its name, Shasta, chaste. However I must leave it though I shall never forget it."

"Linkville, Ore., September 4, 1879. Sweet daughter. * * The two Klamath lakes are connected by a river, out of which the Klamath river runs to the Pacific ocean. This place is only 12 miles from the upper Klamath lake. I walked up to it to-day."

"Silver Lake, Oregon, September 18, 1879. * * They gave me an old Klamath chief as a guide from the Agency near by. But he could not talk English and so I got very little information from him and he could not understand me. So on the second day out, I found a wild young Modoc, Pete by name, who can speak pretty well, and I hired him instead. Old Chaloquin carried his bag of Wokus for food. This is the roasted and ground seeds of the yellow waterlily, forming something like cracked wheat. They carry a cup and mix the wokus in it with water. It swells up and makes a very agreeable mush with a taste between Farina and coffee.

Modoc Pete started with us on the third day. I was determined to get to this place on that day, and so I put a can of tomatoes, some hard-tack and some bacon in my saddlebags to guard against accidents. I left the wagon behind and rode off through the woods with wild Pete. * * * Soon after we came down on Siacan valley—which is ten miles across and is covered with grass. The creek of that name runs into it, and is lost in a great bed of rushes. * * *

From this valley we saw a large, pointed mountain N. E., with a naked cone on top. I crossed the first range of hills at its foot and then got off my horse and had my guide to mark on the ground a sketch of the remainder of the way. I was still 20 miles from this place. I then sent him back to bring on the wagon, and came on alone. I passed a valley where some horses grazed, but no one lived; and leaving it I crossed a hill of lava rocks where I lost the trail, as it did not show. I found it again and soon came to a part of the mountain side where the woods were on fire. This I soon passed, and presently came out of the forest into a great open valley which seemed to be covered with "sage brush." There were mountains north and west, but east the horizon was like that of the sea. I had reached Silver Lake valley which is a branch of the Oregon desert. Pretty soon the road forked and I was puzzled. I am very careful about traveling alone in a sage brush desert for one may easily die for want of water. I rode up on a hill and took a better view of the country but got no satisfaction. The large mountain now behind us, was evidently an old volcano, and its sides were covered with pumice and lava, and lava capped the low mountains to the north. I chose the principal road, thinking that right or wrong it would lead me to

water. I followed it say ten miles and the sun was just going down when to my delight I came on the banks of a cold stream. Horse and I enjoyed a good drink, and I started again. In a few miles I reached the Eugene road and found a house. The Indian's sketch had not been correct, for I now knew where I was. * * * "

"San Francisco, October 16, 1879. * * Monday I reached Eugene, and found Prof. Condon in. I found him a man of heart and head. I formed a friendship which I hope will last long.

Leaving Eugene I reached Roseburg at 7 p. m. and the stage for California left at 9. It was daylight as we crossed the Siskyion which were whitened with snow, and once more Shasta towered on our left. * * * We crossed high ranges in the night and descended from level to level most of the next day. The roads were mostly good and the way we drove would have made my hair stand up had I not been used to it. We whirled round the zigzags by which we descended the mountains, several thousand feet. The last rush was down the Trinity mountain. From it we saw the upper valley of the Sacramento." * *

"November 3, 1879, San Francisco. Dear F. I am likely to get from Gen. Rosecranz a complete series of the coals of this coast. If I succeed I will deposit them in your department. Permanent Exhibition." * *

"September 22, 1880. Dear F. I would like to deliver the three lectures on two Monday and one Wednesday evenings. In January two and in February one lecture. I would like $15.00 per l. to cover expenses, that is unless by so doing I impair the effectiveness of the Franklin Institute in some way.

When you must have the subjects let me know, and I will send names.

I suppose you know the Council of Chiefs voted the $3,450 obtained from July 5, as follows: Frazer, $800.00, Cope, $1,600.00, Barber, $800.00, Hazard, $200, who? $50. P. S. I wish to see you on A. N. S. matters soon. Can't you spend a night here soon?" * * *

In 1879 Prof. Cope published thirty-two scientific papers.
In 1880 Prof. Cope published thirty-one scientific papers.

"Sante Fe, August 3, 1881 * * I came down by the R. R. west of the Rio Grande, after crossing the Rockies at the Veta pass. * * While on the route a tremendous rain fell in the adjoining mountains and several torrents came rushing across our course. Some followed old channels, but much water took new courses, and tore up everything in the way. We crossed several that looked alarming, but reached one at last that was too violent, it raised waves 5 feet high and carried trees and stones before it. We stopped between two of these roaring floods, and for a while it seemed doubtful whether we could get in that evening. However they fell before late, and we reached here for supper. * * "

"Nutt Sts., N. Mex., August 15, 1881. * * The plagues of the country are rattlesnakes, lightning and Apaches. I killed two rattlers

yesterday of different species. One is the same kind found in Kansas, Wyoming, etc., the other is a southerner, very handsome and rare in collections. It is Crotalus molassus or the bull-dog R. I put a stick on his head, and cut his backbone near the head with my knife. I have seen two other kinds of rattlers and secured one for my bottle. The flowers continue beautiful. I send by mail to-day a box which contains flowers surrounded by wet paper. I am told that when soldered air tight they will carry and keep green for a long time." * *

"Fort Wingate, N. Mex., August 30, 1881 * * We railed as far as near Laguna, and had to take a wagon and go round a broken bridge and damaged track, meeting another train 4½ miles beyond. The driver was very slow and when we reached the place, the train had gone. We sat down in the weeds and waited two hours, and it came back, quite accidentally the conductor said, and we got aboard and rode some 25 miles. There at 9 p. m. he put us out at a place called McCarty's and turned about, and left us as soon as possible. We were not pleased and looked round for lodgings but found none. There were two houses—station house with no waiting room and a section house for workmen. I got out my blanket and laid down on the platform between some boxes and trunks, and got to sleep. A cold wind sprung up and gave me the creeps. I was wakened once by an animal fussing round my head, I found it was a friendly cat, and was glad to take it in for the warmth. In the meantime we had telegraphed for relief, and learned that a train would come down from near this end, and take us off. It arrived at 3 a. m. and we got in and steamed away. By 8 a. m. we were at Wingate Station—where a box car serves as a station house. We sat on the mail bags and ate breakfast from our satchels."

During 1881, Prof. Cope published forty-five scientific papers.

"Rocky Bar, Idaho, July 5, 1882. * * Early in the morning of the 2nd we reached Blackfoot and took a seat on top of the stage. That day and night and half the next day we spent in crossing the desert of Idaho—where sage brush or nothing grows on lava or sand.

"Dead Mans' Canyon, near Lakeview, Oregon, August 2, 1882. * * Soon after leaving Todwell the road crosses a high divide which separates the drainage of the Alkali lakes from that of the Warner lakes. We had a very fine view, with Stein's mountain to the N. E., and Warner's mountain to the N. W. Behind lay the Alkali lakes; and close by lake Annie and the Cowhead lake. Before camping that night we crossed the line into Oregon. * * * I caught near Twelve Mile Creek a fine bluish whip-snake. We reached Warner valley near noon and found the road good thereafter. This valley is 100 miles or more long and is bounded on one or both sides by high basaltic mesæ. The bottom is flat and contains a succession of swamps and lakes connected by a large creek. Next day we passed

Sarner lake No. 2, a beautiful body of water, alive with pelicans, gulls, duck, etc., with shores abounding in snakes.

Towards the close of 1882, the present writer, recognizing that Cope's value to science, and especially to the Academy of Natural Sciences, was being impaired by countless antagonisms based (for the most part) on entirely intangible grounds, determined if possible to bring together Cope and one of the most important of these scientific men in the Academy who had been opposing him. The latter expressed himself willing to meet at the writer's house at dinner. The following note was Cope's reply to the proposition; which, on this account, very unfortunately fell through. The proposed reconciliation was not effected till ten years after, too late to have exercised any influence on his career.

"Philadelphia, January 5, 1883. Dear F. In re * * perhaps a little billiousness may give me a slightly discouraged view of things, but I do not feel very sanguine of the results of an interview so long before and so soon after the annual election.

I have persevered for many years in endeavoring to accomplish some changes in the Academy N. S., and they have not yet gone far enough to be of use to me personally. After having been abandoned by enough of my friends to make further work useless I have for the first time, this year, concluded to drop the place. I have resolved to leave the matter to those who may be interested in it, and turn my attention elsewhere. This means for me to leave the city for the rest of my life, if opportunity presents. I have fully determined on this.

You see it is absurd for me to go into an institution where every position is elective, where I have a majority of personal or political enemies. That this is the case is now satisfactorily proven to me. I cannot ask anything more of my friends.

Now I will meet ——— on one condition, and if you choose or think best you can tell him so. I have no propositions to make and no favors to ask. Everything must come from him. I regard him as my worst enemy in the A. N. S. personal as well as political. The only basis on which I will connect myself with the A. N. S. is that it abolishes the elective part of its organization so far as it safely can, with regard to its scientific experts. This will be done by two methods. (1) By creating an order of Fellowship, which shall be open to experts of established reputation only. (2) That the officers shall be selected from these only as in the Boston and New England Societies. (3) That the professors shall be ex officio members of the Council.

I have little hope of ——— agreeing to such propositions. For myself I will not risk time or property on anything less.

If you however think that any good will result from such a meeting I will be present at your invitation, and will hope for the best." * *

"N. P. R. R. near Fallon on the Yellowstone, September 9, 1883. * * * Yesterday noon I got in from my Little Missouri expedition, and took the train at 3 a. m. for Helena this morning. The trip lasted nearly ten days and was in some ways very satisfactory. I did not get what I went for, but I made a special discovery, which I did not expect. * * I got 20 species, 14 of them Mammalia. The most abundant rhinoceroses, of which I obtained the greater part of a skull, besides many other parts and specimens. The next most perfect was the hog with legs to his chin, of which I had but one specimen before, which I got in Colorado in 1873 named Elotherium ramosum. Then there are a small dog; a sabre-tooth tiger, large, three-toed horse, etc., etc. I made another camp by a stream of white sand. We dug 3-4 holes and got beautiful water. * * The discovery of the fossil bed in question enables me to extend the Lower Miocene (White River) formation 200 miles N. W. of its most northern boundary previously known." * * *

"Colorado Springs, September 19, 1883. * * I expected to get a certain fine fossil fish specimen I saw at Fossil station. I succeeded and on examination found it to be a new kind of a gar, which had a blunt nose instead of a long bill, as most gars have. I went exploring among the red-beds below the fish beds and took out with my own hands the skull and part of the skeleton of a Coryphodon about as large as a cow. I set a man to work to get the rest of the skeleton. * * Meanwhile I bought very cheap, two stingrays and other things, with a very peculiar fish related to the sturgeons, and what is most interesting the skull of a large bird related to the ostrich, which is quite new." * *

"Eight miles S. of Plaza, Socorro Co., San Francisco Canyon, New Mexico, October 10, 1883. * * Two days I spent in fishing with my net, I found many fishes of only five species, all very rare, and one probably new. I caught a totally new species of water snake of a new genus. It is a pretty thing 31 inches long, with 7 rows of brown spots on an ashen ground. I sent a description to the Naturalist under the name of Atomarchus multimaculatus.

* * * I hung up the coffee-pots, water-pails and frying-pan on a short limb with hooks and crooks, and old grizzly will have to stretch to reach them. I put my bed on a little higher ground than the rest of the camp, where holly leaved oak, Spanish bayonets and huge cacti dot the grass. A hole under a large rock near by is inhabited by—I don't know what, but it'll have to speak loud if it awakes me to-night." * *

I dreamed of home the other night, I will see what I can do to-night." * *

"Perry's Ranch, Mogollon Mts., October 13, 1883. * * As we went to bed, the wind blew cold so I laid my blankets behind a cedar bush, and under an oak. In the night I was awakened by a snorting

near my head, and looked and saw a huge bull in the moonlight, regarding me intently. I suddenly rose with a noise and the beast wheeled off but didn't go far before he commenced plowing the earth with his horns. A few stones induced him to take himself and gypsy cattle with him, out of hearing. Soon after I got to sleep, a rat, or vermin of similar size, ran through my blankets from my heels along my back and emerging at my neck with considerable celerity."

"Monterey, Mexico, (?) November 2, 1883. * * The situation of this city is the most beautiful I have ever seen. * * * Huge Agaves elephants among plants, grow along the road sides; and one species of Yucca forms trees of strange aspect, each branch terminating in a head of "Spanish bayonets." * * A fine stream rises near the town by a spring and soon becomes as large as Cooper's creek at Haddonfield. * * * Its waters are perfectly clear, and are full of fishes. I caught some specimens with hook and line, and got the boys to catch some for pay, and so have secured a good collection. I got these species: Spiny-finned Chromidiæ, 1 species; Percidæ, 1 sp. (Sun fish); Soft rayed fishes, Cyprinidæ, (minnows, etc.) 3 sp.; Cyprinodontidæ, 1 sp.; Characinidæ, 1 sp. Total 7 sp.

Now the Chromididæ and Characinidæ are southern hemisphere fishes, while the others are northern hemisphere; so here it is that they meet and mix together. I never knew just where the line between the Neotropical, and Nearctic faunæ (as they are called) should be drawn before. I went out walking one day, and the lizards showed me the same thing. I caught four species; two belong to New Mexico and Texas, and two to Mexico. The birds are mixed in the same way. The wrens, blackbirds and a good many others are Mexican, but our dove and meadow-lark are here."

In 1884 Prof. Cope published fifty-seven scientific papers.

"January 8, 1885, Dear F. Let me congratulate you on our election to offices of honor if not emolument in the A. P. S. * *"

"Near Ortiz, Chihuahua, Mexico, March 4, 1885. * * My first trip (to Monterey) was in November, 1883, a little early. My next was in April, 1884, a little late. Right here it is spring. Cottonwood trees are coming out in tender young leaves, and the peach trees are in bloom. On the grassy plains millions of small birds probably migrating, and accompanied by hawks of several species. The ground between the low bushes of Larrea mexicana and Koeberlinia spinosa was for a distance covered with a close carpet of pink-purple flowers."

"Zacualtipan Hidalgo, March 15, 1885. * * The Valley of Mexico, when all its surroundings can be seen, is one of the most beautiful places I know of, and is perhaps not excelled in any country. I will never forget the scene as the train sped on its way towards Vera Cruz on the morning of the 10th. We got off at Irolo and took a pretended railroad for Pachuca. It turned out to be a horse "railway" by Brill, of Philadelphia, which ran down hill most of the way by gravity, and was pulled up a few hills by mules. We passed through

huge fields of Agave, passing some mountains, and reached Pachuca by noon at the foot of some high mountains. We had fresh pulque—which is a white effervescing drink which tastes like a mild mixture of cider, lemonade, and beer; the best drink I know of, take it all together.

When we left we climbed up a stair-case of rocks for a great height. The vegetation became that of dry places, mostly cacti. In the valley there are many beautiful plants. The Acacias, with their sweet flowers, are numerous. Several stand in the barn yard. On one of these was a great bunch of a parasitic orchid, with beautiful pink flowers. On another from the midst of another similar bunch arose a parasitic cactus, and on this again grew a parasitic Tillandsia!

The houses here remind me of the Tyrol. They are of stone or logs and have roofs, in great contrast to the mud (adobe) houses of other regions, with flat tops. This town is very picturesque. The ground is irregular and a beautiful, clear creek runs thro' it. The people are very fond of flowers and have rows of pots along the rails of their porches. They generally have several cages of birds—one parrot, and a lot of song birds. Among the latter the Clarine is easily queen.

The valleys are very deep here, running from 1,000 to 2,000 feet below the level of the highlands. One goes from the Tierra Fria to the T. templada and T. caliente in a very short distance. Oranges in fruit in the valleys, blackberries and oaks on the hills! The temperate region above; the tropics below. I caught 7 species of lizards and frogs, and a French doctor gave me 7 species of snakes. Five or six of the latter belong to the "Cope family." From the clays of the coal beds I went to examine I procured 2 sp. 3 toed horses; 1 camel, and parts of a Mastodon, so that I can fix the age of the beds as compared with those around them. I examined some iron mines also, which are in another formation."

"Vera Cruz, March 23, 1885. Just before leaving my friend Julius Flohr took me to see the lake Xochimilco. We caught numerous water snakes on the banks, one of which is a species which I have named, and which is probably one which is on the coat of arms of Mexico. I have met various Americans on the way here who will mostly be passengers on the steamer Whitney tomorrow. They may be distinguished generally from the Mexicans by their bad manners. They are not Philadelphians, who compare favorably. Some of these are evidently western people. The Indians are more polite than the lower class of Americans, and are better people I believe."

"Galveston, March 26, 1885. (?) We stop here an hour and I take this opportunity of mailing this. We reach New Orleans to-morrow. I was sick the first day and have been miserable ever since."

"New Orleans, March 31, 1885. The Exposition here is a fine thing, though not to be compared to ours in 1876."

"Granger, Wyoming Terr., September 18, 1885. * * My health has been greatly benefitted, and I feel like a Western explorer again.

After leaving the geysers we rode East 30 miles to the great fall and canyon of the Yellowstone."

During 1885 Prof. Cope published sixty-two scientific papers.

"Philadelphia, February 9, 1886. Dear F. I wish to suggest apropos of your committee Am. Phil. Soc. that one of the easiest ways of regulating the question of election of suitable members is to restrict the number to be elected per annum. In case of the A. P. S. it might be restricted to 12 or 15. In this way many inconvenient questions are answered, and the membership is made worth something." * *

"Washington, D. C., February 29, 1886. Dear F. Yours is received and I am interested to hear the news. It is disgusting that Miss —— was defeated, and I venture to say that she will some day be elected." * *

He was right, she was.

"Washington, D. C., May 16, 1886. * * I sent MS. of a small book to Putnam's, New York, a few days ago. It explains the results of my studies in evolution in the field of theology and ethics. I can prove, I think, the pre-existence of mind, i. e., as existing in living matter before it has developed complicated structure. In other words, structure has been produced by motion (of the animal) (theory of "kinetogenesis"); and motion has been in the first place directed by sensation, or consciousness—(a synonym), which is a quality of mind only—is in fact the foundation of mind, which with the assistance of memory, has built up the mind of animals and men, I have learned the connection between the motion of animals and the development of their structure by my studies of paleontology. It is a satisfaction to me to be able to prove the fatherhood of mind or personality over living nature. It will be the next step to prove that it has been so over dead nature also.

"A beginning in this direction can be made by considering two facts. One is that the matter of living things (protoplasm) cannot maintain chemical stability at ordinary temperatures without the presence of life. Second, that plants compel chemical combinations of a complex character, (oils, resins, waxes, etc.) which do not occur in nature (except as products of vegetation), and have to be produced by intelligent men in a laboratory. This means that there is in life some power which can control chemical energy. I once called this kind of energy "autichemism". Chemists generally do not believe in any such thing. They think that because they can build organic compounds in a laboratory, therefore the plant is not endowed with any particular power. But the capacity to bring the compound together to the exclusion of others which are present, indicates in the plant something like the selective power of the chemist in his laboratory. The instability of dead protoplasm is still less easily explained.

"I am curious to see what will become of my hypothesis in this

direction. So far as the evolution of animals goes (man included) I consider it unassailable. The rest is not yet made out. It is for the future to decide. But it will give new interest to physics and chemistry. I hope it may prove the beginning of the scientific proof of the mastery of mind over matter, instead of that of matter over mind.

"It is true that mind is under the dominion of matter, as it is an attribute of it—but not entirely so. In the proper way, and at the proper time, mind controls. To find out how this is, and when and where, is the great problem of science; also therefore of progress and prosperity." * *

"Washington, June 9, 1886. * * I learned several things in the time I have lived. Nothing affords so much satisfaction to the mind as the consciousness of having done right, not but that the best people must have regrets for having also done wrong on some occasions. Then we can take comfort in the knowledge that God knows our incapacities and our defects, and pities and helps us; the latter especially if we try to help ourselves. But there are many triflers in the world, people who avoid doing anything of any value or importance. It is very desirable not to be compelled to live with such people. Any one who feels the seriousness of life, and the certainty of its termination, will not waste it" * *

"Washington, D. C., December 18, 1886. * * I started to write my paper, read before the Natl Acad. Sciences "On the Phylogeny of the Placental Mammalia"; but I found the work so extensive that I could not get it finished in time. So I concluded to turn it into a book and call it the "Genealogy of Man and the Mammalia" and see whether I can get a publisher.

My book "Origin of the Fittest" is out. * * It is nicely printed, and looks well. I have several complimentary letters about it already. * *

Now I must get to work while I am fresh on it. My head is full of crescents and cones and cannon bones and naviculo-cuboids." * *

In 1886 Prof. Cope published forty-seven scientific papers.

"Washington, February 5, 1887. * * The woman suffragists say: 'If blacks can vote, we should also.' Perhaps so only I would reverse the proposition and say since white women cannot vote colored people oughtn't to either. In truth there should be some test or qualification for voting so that a great many ignorant men would be cut off. We have too many incapable voters now, and to give suffrage to all women would be to increase the number very greatly. * * *

I have heard women complain of injustice on various accounts; as for instance lower wages than men; also of dependence on men; and of the control of men. Men may and do at times act unjustly, but the above conditions are the fault (?) of nature, and the order of things and not of any particular man or men. The part the women play in the natural order of things is totally different from that of men, so much so that in those things in which they differ, the same rules do

not apply to both. But some men and women forget this and talk differently." * *

"Washington, April 15, 1888. * * I took a walk the other day and got some nice plants which I have seldom seen wild, as leather wood (Dirca) which is cultivated at Fairfield, and Dicentra cucullata (Dutchman's Breeches). I saw a couple of men in the woods, one stout, the other smaller, looking about. They watched me turning over logs, etc., and did some laughing, amusing themselves highly at my expense. In issuing from the woods I walked near the men, and as they turned to look at an embankmentI nearly ran into the largest one, who proved to be president Cleveland He gave me a military salute, which I returned. .

Among other things I brought home from my walk a handkerchief full of the eggs of Rana clamata. I put them in my washbasin, and they hatched and I have now several hundred small tadpoles swimming actively. They lost the right gill some time ago, but the left one still remains. It will soon go, and the work of the internal gill will begin. I propose to work out the history of the development of the fore leg. This is very singular in the Salientia (the right name for Anura). They grow within the bronchial space under the skin, and acquire a skin of their own. This is probably by imagination (?), or at least it ought to be; but I have not yet been able to detect it. The legs come out through the bronchial orifice, and the two skins join, forming a seam that is long visible in young frogs.

I have worked out the history of the ear bones of frogs, that is of the two terminal ones, called incus and malleus. Neither of them is a part of the hyoid or quadrate arch at any time, so they are not the incus and malleus of Mammalia, but distinct structures. Sundry arguments based on the supposition that they are those bones, thus fall to the ground! Dissecting tadpoles' skulls is nice work. I do it with a pin, a pair of tweezers; fine scissors, and a glass of X 50. The changes in these skulls in growth are astonishing. I found one queer thing that I hardly expected. At one time the relations of the hyoid and auricular apparatus to the skull in tadpoles is quite the same as in certain salamanders (Plethodon, Spelerpes); but the stage does not last long. It is great fun to hatch out batrachians. I saw no end of toads on my walk. They form long strings and coils thus" (sketch) * * * "and they are very pretty. But they are not so. good to study as frogs, as the toads develope at so small a size that they are difficult to dissect and see. Remas, Acris, Chorophilus, and Hylapickeringii are noisy now. I suppose they are at Bryn Mawr also. Did thee ever catch the last-named? You can do it best with a lantern in a swamp at night. They are not then so easily frightened, and they will let you creep up on them, without becoming entirely silent. One can see them best by the ripples on the water when they whistle or by the shine on their throats." * *

"Washington, D. C., July 15, 1887. Dear F. * * I have

had a parrot and monkey time with ——— over the Naturalist, and the end is not yet." * *

"Phila., July 23, 1887. Dear F. Your reply to ——— is both pointed and just; in fact just what he ought to have. I would with your permission publish both, were it not that it is I think best at present to avoid consolidating the Survey opposition." * *

"West Falmouth, Mass., August 23, 1887. Dear F. Your article will go in all right, if possible; I will probably have to cut something else. It should go in at once. * * Some of my friends are exerting themselves to secure for me the place to be shortly vacated by Langley in the Smithsonian. He will in all probability become secretary of the S. I. and the place of Asst. Sec. will be vacant. G. Brown Goode will become director of the National Museum and Chief of the U. S. Fish Commission, but some one will be necessary to fill the other vacancy. The person must also be a Naturalist, since Langley the sec., is a physicist.

If you feel disposed to aid me in this a few letters from you would prove very valuable." * *

"West Falmouth, Mass., September 1, 1887. Dear F. I have just seen your review of ———'s address and I am glad to see you advertise his nonsense * * Also I don't believe that geologists now-a-days regard Upper and Lower Silurian as parts of one system, any more than they regard Upper and Lower Merion as more alike than any other two places, or N. and S. Carolina." * *

During 1887 Prof. Cope published forty-eight scientific papers.

"Washington, D. C., June 10, 1888. * * Every mental process costs physical energy, the act of willing among the rest; but is there any relation between the energy (measured by weight or momentum) and the nature of the thing willed? It can be shown that there is none, and to show this is the object of my paper. To prove this is to prove the superiority of mind over the law of the conservation of energy, and that is to give mind a controlling influence in the universe, which it would not have if it were not so superior. Others hold the same opinion, but their views are speculative and not brought into connection with modern science." * *

During 1888 Prof. Cope published forty-nine papers.

"Phila., March 28, 1890. Dear F. I enclose your MS. with a few comments on the margin. I think the Open Court will publish it.

I have been in Washington and the Sec. Interior told me that he was satisfied that my collection belonged to the U. S. Govt! This huge steal appears to have taken strong hold in Washington. I have put the thing in the hands of ——— and I return to-morrow, and will place the facts in the hands of several members of the House Comms. on appropriations. I will busy myself in exposing this villainy. Fortunately I have some strong ammunition." * *

During 1889 Prof. Cope published fifty-two scientific papers.

During 1890 Prof. Cope published thirty-nine scientific papers.

Phila., September 9, 1891. Dear F. I went to the Congress. As an editor I could not ignore it, as I wanted material for various reasons. * * Gaudry and Boule and Zittel and Jaeckel spent two of the latter days of the Congress at my house here.

The feature that displeased me most was the fact that the western excursion cost the foreigners $265.00 apiece. I would like to know about what the same would have cost if the meeting had been held in Philadelphia." * *

During 1891 Prof. Cope published thirty-nine scientific papers.

"Phila., May 3, 1892. Dear F. Spring has arrived at last after many delays and the country is delightful.

In a day or two I go to N. W. Texas on the Geol. Survey of the State to explore the relations of the Permian to overlying beds, and I expect to be absent several weeks. I am just finishing up proof reading of several papers in the Trans. and Proc. of the Am. Philos. Soc.

——— has been making an exhibition of himself again. He has been redescribing and rediscovering most of my important discoveries in paleontology of Mammalia for the last 10 years! He names the order Condylarthra the genus Meniscotherium, etc., and rejects my generalization without credit as if they were new. As my work has been generally adopted in Europe, ——— will find he has given himself another serious blow. I give him a review in the May Naturalist. * * You will be interested in learning what a Waterloo befell the old Academy ring two weeks ago. The new men there got tired of waiting for the erection of the huge building planned by these gentlemen, which would absorb all the money and time within reach of the Academy for the next 10 years. So they got up a plan to erect a wing with funds actually in sight. They were opposed, and when the committee reported, there were two reports. * * They were totally defeated by large majorities. The new building will be under roof by autumn, and next winter will see a campaign to raise funds for endowing professorships.

"The world do move" and the work we carried in 1876, is like to be realized in 1893!" * *

"Espuella, Dickens Co., Texas, May 22, 1892. * * This place is about 20 miles E. of the east wall or front of the staked plains. I have often wanted to see this region and understand its geology, as it furnishes the connecting link between the geology of the center and Gulf-Atlantic regions of the continent. We followed up this front wall from near Big Springs (125 miles), and will go yet further

north. * * * We usually get breakfast about sunrise, and noon for an hour, and take a nap in the shade, if there is any. We have very little twilight in this latitude but night comes on soon; so we go to bed about nine o'clock. * *

Since leaving Big Spring we have seen but two springs, and but two running streams. Numerous stream channels full of sand come down from the staked plains, but the water is below the surface and has to be dug for.

We have made several camps on dug water, and sometimes it is good and sometimes bad. It is sometimes salty and sometimes soda-ish in taste. * * *

I never saw so many prairie-dogs, as it is one continuous town from Big Springs here (100 miles). I executed a goodly rattlesnake by slipping a twine noose over his head, and I have him, with various other snakes, lizards and fishes, etc., in alcohol. Lizards are numerous, and one I caught, a large green Crotaphytus, bit me his best; but he only cut the skin a little." * *

"Mount Blanco, Crosby Co., Tex., May 29, 1892. * * After leaving Espuella we camped at a beautiful spring, where on an overhanging ledge, about 500 pairs of white fronted swallows were building their mud nests. It is the same species that used to build on my barn at Thorndale in the Chester valley. Here we had owls and mocking birds and scissor tails, and water-snakes and numerous other wild things.

All that we obtained keeps up the great difference between the fauna of the Trias and that of the Permian below it, that prevails in other parts of the northern hemisphere.

On White River we had good water, or would have had but that a dead steer or cow lay in it every little way. Many hundreds were lost here during the late drought and many of them tottered to the water, lay down and were unable to rise again.

Yesterday we moved up here and spent part of the day exploring the bad lands of Mont Blanco. We had better success than hitherto. We found in part of a day; parts of a Mastodon; teeth of several horses or one species; lower jaw with all the teeth of a large camel; and a huge turtle, 3 feet in width, certainly new. There are odds and ends of other things, and I haven't much doubt but that we will make a good haul. The horse is Equus simplicidens Cope, and it keeps its characters perfectly. The camel belongs to Plianchenia (Cope)." *

"Mont Blanco, Texas, June 5, 1892. * * We have taken out thus far 13 species, two of them turtles, the rest mammals. The mammals are mostly large, including Mastodons, camels, horses, and sloths. Of Mastodons we have three species of which two are probably, one certainly, new to science. The camels and horses are all new. One of the camels is as large as the living species; another is larger. One of the horses has teeth equal to that of a modern horse, another species is no larger than an antelope. The sloth is as large as a cow. * * I found sure enough that the people were mostly orthodox Friends

from Iowa Yearly Mtg. I had never heard of it before. The teacher of the community is a Prof. Moore, who was a student of Earlham, and of Haverford after I left there. The people are superior to the general run of settlers in this country, as their origin would indicate." * *

Camp on Holmes Cr., June 10, 1892 * * * Insects are very friendly here. They accumulate under anything you lay down in the grass, for shade; and fluids attract many. Two beautiful moths came to my mouth for a drink last evening, and another has just now quenched his thirst in the same way. Beetles get into the bedding but do no harm, but large ants are very "bad medicine,' as I concluded when I was stung by one last night, and hopped suddenly out of my blankets. If I get up in the night I move with great care for fear of "cow-killers" (multillas). A small kind stung me yesterday. Horned and other lizards and rattlesnakes abound." *

"Clarendon, Texas, June 13, 1892. Dear F. Your very welcome letter from Paris reached me at the cow-village of Espuella in the Pan Handle of Texas, and this reply finds me 125 miles north of that place, still further "panhandled". At the Denver and Ft. Worth R. R. town of Clarendon. It has say 1,500 inhabitants and is quite civilized. E. g. good beer is 5 c. p. glass and soda water do.; a rarity in this country where they charge 10c or 25c for two drinks.

I have had a ride on a gray stallion of 250 miles (from Big Spring on the Texas and Pacific R. R. almost due S. of here), and am much the better of it in health. We have had all kinds of weather except rain, and this is a dry season for even this dry country. The weather has been alternately cold and hot, often presenting a difference between day and night of 30 to 40 degrees. * * *

Scientifically we have had a successful trip. Our line has been along the eastern escarpment of the Staked Plains, with an occasional excursion on the plains and across its spurs. We have accessible Permian, Trias, Loup Fork, and Blanco beds. Lower down the country we had Cretaceous-marine; all the beds here are lacustrine or estuary. The Blanco beds are above the Loup Fork and contain a Cret. fauna, mostly mammals. We have so far 14 species, of which 10 are new to science—2 of them Mastodons. The Loup Fork beds we have just discovered here—and the fossils are very numerous. We found a grave yard of horses (3 sp.), camels (2 sp.), and Mastodons (1 or 2 sp.). The ground was covered far across with their bones and on the bank we got out in a few hours, 6 nearly perfect skulls—all horses. So far no Carnivora, but we will get them I suppose. We got none on the Blanco bed. This formation forms the entire surface of the Llano Estacado, and is underlaid by Trias and Permian. We only found the Loup Fork here, and how far passes under the plains we have yet to know.

Your information from European sources is very interesting. You did right in talking with Profs. Cappellini and Daubrée. I am not proud of my share in the Cuvier Prize.

The cast that is in Paris, which belongs to me is Hyracotherium ventielum, and is probably in the Trocadero, where the last Exposition material was partly deposited. I want to sell it for $50.00, provided it is still in existence. If you could find out for me I would be greatly obliged. If you could suggest me some one who would buy it I would be doubly so.

We left our pretty camp with regret, with all the birds that nested in the cottonwoods. I also left a pet rattlesnake who lived in a certain hole with two entrances, at one or the other of which he was lying every day as I went to and fro after fossils." * *

"Madison, South Dak., July 5, 1892. * * The country is mostly rich prairie in fact except the Black Hills and the bad lands, this entire state is simply grassy prairie." * *

"Rock Creek Sub-Agency, Grand R. Dak., July 17, 1892. * * By noon we reached Miss Collins' house at Little Eagle's settlement on the Grand. She received us very hospitably and kept us all night. Here mosquito bars made life endurable. She is a Massachusetts woman, has quite a taste for natural history and she has a collection and a library. She is much respected by the Sioux, who call her Winona, "the first born." * * As it grew late we turned down a low hill to the left and climbed a low bench at the foot of an opposite hill. I saw a low base bank and lying around white objects. I told Oscar to let me out, as I thought I saw bones. Sure enough the ground was covered with fragments of dinosaurs, small and large. Soon we found water, and stopped for camp. The Sioux boy motioned me to him, and showed me a low clay hill ⅛ mile S. We went to it, passing over fragments of bones all the way. But at the hill were numerous bones of giants nearly entire; one could hardly walk without stepping on them. Presently I stopped before a curious object buried deeply in the ground, and behold the nearly entire skull of a great reptile related to Hadrosaurus, some 3½ feet long. * * In the 3 days I collected, I got 21 species of vertebrates, of which 3 are fishes, and all the rest reptiles except one mammal. This last is a fine thing, the most valuable I procured, and new as to species, at least; and it throws important light on systematic questions.' * *

"Phila., August 2d, 1892. Dear F. I received your card announcing your return, while I was in Dakota. From the tenor of your letter from Paris, I had supposed that you would have remained longer. I wrote you to Paris in reply, and perhaps the letter has been returned to you by this time.

I am just back with a booty in 40 cases of remains of Vertebrata. Some nice things!

I have your paper criticising the biography of Leidy. I enjoyed it considerably, as a work of art. Essentially however, I think the memoir is the only rational, or judicial one that has appeared, and am not inclined to be hard on its author on account of it. * *

During 1892 Prof. Cope published thirty-seven scientific papers.

"Philadelphia, June 15, 1893. Dear F. * * I am well sometimes and when a little off I know the treatment, so that I can cure myself.

I go in a week or so to N. Dakota with Brown of the University, to collect saurians in the Laramie.

Thanks for your kind recollection of me. If possible I will come out to the Inn to see you before I go, but cannot say positively. * * * * * * P. S. I want to mention something else. You are a very generous man, and have been so to me often. But in one point you consult your own feelings in a preëminent degree. I refer to the Academy N. Sciences. Just now is a turning point in its history, and very probably in my fortunes as well. If a favorable council is secured I will go in as Prof., Vert. Paleontology, probably as a life position. * * If not, I am left, so far as Phila., is concerned, and probably in other ways for several years; perhaps always. * * We will not get out the full force for * * Tuesday next, and the others are as usual, the loafers and Co. We need every vote. Won't you cast one for us?" * *

"Fort Supply, August 20, 1893. * * In the evening we left for Kansas City, where we found the train for the Panhandle would not go till night. We concluded to put in the day at the University of Lawrence instead of at Kansas City. * * We examined the University Museum before dinner with Prof. Hayworth, as both Prest. Snow and my friend Prof. Williston were absent. * * The first afternoon Lieut. Fox took us out to the "Devil's Gap," five miles north of here, and we found the geology interesting, and partly new. We found a great bed of fossil shells which I recognized as a Texas formation, and under it the Red Beds which I came to study. We found some bones on the top of these, and I am in hopes that we have found a formation of some importance." * *

"Miami, Texas, August 24, 1893. * * We made three expeditions out from Supply to the fossiliferous beds we discovered, and got a fine box full and shipped them to the Academy of Natural Sciences. With them I sent a bottle of alcoholics, for lizards and snakes are rather common. It rained one day so we stayed at home, and the next day the country bloomed with flowers. Chief among them is a lovely Sabbatia (Gentianaceae), of which I enclose a specimen. * * We explored the Trias round Fort Supply without result. It is a provoking formation, for fossils are very hard to find in it. The formation we are in now is rarely so disappointing, although we may have to go to Mobetie before we find anything." * *

"Wellington, Kansas, September 1, 1893. * * Everybody in this country is interested or excited about opening of the Cherokee strip, which forms about one-third of the territory of Oklahoma. It is one of the few parts of the United States where a man can get a homestead of 160 acres at the government figures of $1.00 to $2.00 per acre. Thousands of poor people, with wagons and camp outfit, are waiting on the border for the opening day and there will be a great

scramble when the time comes. The fastest riders will get the land. Men are practicing horses about Hennessy, preparatory to making the run for a home. Excepting the western third, the strip is a good country. Crops look very well about Hennessy, and the settlers are mostly of a good class.' * *

During 1893 Prof. Cope published fifty scientific papers.

"Philadelphia, May 24, 1894. Dear F. * * It is very possible that within three months I may not have any place to work in, nor any place to store my collections. * * The men of means connected with the —— who have promised a good deal, have failed me, and I have no longer any hopes in that direction. * * I was touched at your presence at my daughter's marriage. * * There is enough money owing to me by the Smithsonian Inst. to enable me to pay the interest I mentioned, but I cannot get it until certain work is done, and I cannot have the work done in time. I have, however, written an urgent appeal to the powers there to let me have enough (one-half) of it, to use, but I expect a refusal." * *

"Philadelphia, May 30, 1894. Dear F. * * A letter from Washington informs me that the senate confirmed Walcott yesterday. I also had a letter practically refusing to advance me $500 of the $1,000 due me when my book is finished. The terms are that I shall turn in one-half of the manuscript so that it shall not be returned, but shall be ready for press This I cannot do without turning in an imperfect job. As I have always proposed to make this one of the best works of my life, I cannot consent to spoil it in this way." * *

"2102 Pine St., December 4, 1894. Dear F. I am anxious lest final propositions as to my collections reach me this week. I also cannot discuss the business propositions in the presence of others except yourself. It seems to me, therefore, that if I could meet Mr. —— sooner than next Sunday, and in private, more would result. What do you think?" * *

Phila., Dec. 16, 1894.

Dear F.:

* * * I saw Mr. —— in Washington, and he said that if he was able to buy my collection he would do so. I clearly understood that he is not able.

I doubt very much the collection's remaining in Philadelphia.

Yours very truly, E. D. Cope.

"Philadelphia, December 26, 1894. Dear F. In order that you may not misinterpret my absence from your usual Sunday evenings. I will explain. * * *

As to yourself I am grateful for your exertion with regard to the matter of the collection and I am only sorry that you were not listened to. From a purely selfish point of view I have done well, but

I am sorry for the Institution that should have had the collection here. My lifelong hope is abandoned." * *

During 1894 Prof. Cope published forty scientific papers.

"Philadelphia, Jan. 10, 1895. Dear F. I hope to see you soon, and meanwhile I acknowledge your note of Dec. 27.

"—— and —— are probably both friendly to me on their conditions but these conditions are precisely the ones which both you and I labored to exclude from the —— years ago, and which those gentlemen are not only endeavoring to fix on the institution; but are carrying into practice in a way hitherto unknown in its history. * * I sold two-fifths of my collection, that is, the North American Fossil Mammalia, at my own price, to the American Museum of Natural History of New York. One-third of the money was raised by subscription. They say they will take the remainder of the collection at my price. So far as I can see they will get it. This is, however, in the future.

"I consider that it is highly probable that the collection would have remained in Philadelphia if I had not entrusted the matter to ——. ——did nothing, but pursued a course which has excited my indignation. Among other things he said that the affair was "my funeral," i. e., the funeral of yours truly." * *

"Philadelphia, March 21, 1895. Dear F. Thanks for the note from ——. If you will allow me to keep it for a while I can probably do something with it through the University. * * I have found the University wide awake in such matters." * *

In 1895 Prof. Cope published thirty scientific papers.

During 1896 Prof. Cope published forty-nine scientific papers.

"Philadelphia, March 10, 1897. Dear Wife. * * I went to my lecture Tuesday and was the worse for it. To-day I took one of my two lectures and am decidedly better to-night. I hope to continue better and give one more lecture to-morrow. If I continue to improve, or even as I am, I can give the lecture at Mrs. Sculls, but I doubt my getting to Bryn Mawr Saturday evening to the Spencer meeting.

"Still I cannot tell so far ahead. I go backwards easily and must keep as still as possible. * * It is unfortunate that we should both be sick at the same time. * * I am well cared for by the Dr. and Miss Brown; and between my spells of pain, I can do some work that enables me to pass the time as pleasantly as may be under the circumstances. My pursuits are fortunately such that they are not suspended by imprisonment in the house. This is fortunate for me, as I find inaction very unpleasant, until I am actually disabled and then it comes natural.

Apparently healthier men than I die about us. I knew —— quite well, and esteemed him highly. He was the best man bearing that

name that I ever knew. My trouble will probably finish me in the course of time, if it goes on, but it can be eradicated by a surgical operation, and that I will probably have to undergo sooner or later. * * gives me a remarkable case of permanent cure of a worse case than mine by some surgery." * *

"Philadelphia, March 27, 1897. Dear A. I had a good night last night, and am feeling pretty well, excepting that I am weak. I am recovering a little my appetite, but my head is somewhat swimmy. The crushed strawberry cushion is doing nicely and gets crushed a good deal.

"The sky looks beautiful out of the window, and I dare say that in a few days the country will be charming. I am anxious to get out, but cannot yet a while." * *

The following is the last letter written by Edward D. Cope:

"Philadelphia, March 31st, 1897. Dear Aunt Jane. I understand that to-morrow is thy birthday and I wish to send my greetings.

"I suppose thee is still an invalid, and if so I can sympathize with thee feelingly. I have been confined to my room, barring a few walks out, for five weeks to-day; some of the days confined to bed.

"I have suffered great pain and am now recovering slowly from the depression caused by powerful drugs taken for relief. My dangerous symptoms have passed away, but the Morphia-belladonna combination makes the strongest constitution stagger The mental depression is dreadful; so that nothing in life is in any degree enjoyable, except an occasional draught of ice water. So I pity everybody I hear of that is sick, and am glad to see so many people well. To be well seems to me now to be something extraordinarily fortunate.

"I hope thee is free from this grievous depression. Whether depression or not, however, I know many suffer more than I do, and so I am thankful.

"I do not expect to leave the world yet a while, but I shall do so when the time comes with the full belief that it will be a change greatly for the better.

"The relation of the Supreme to men is that of father to children, and if we keep the relation true, He(?) will not fail. To be sick is good for us sometimes. It corrects our perspective of human life, and sets things in a proportion which we must sometimes see.

"In active life we have our special pre-occupation of mind, and see chiefly those things.

"So we do our work; and must do it; but to take a pause sometimes is good. This applies to me, for I have many enterprises going on that need close attention, and other things cannot receive much attention. * * May physical comfort attend thy coming years; mental peace thee knows how to have, and may it remain.

Thy affectionate nephew, Edwd. D. Cope."

The twelve days which elapsed between the date of this last letter and his death, he passed in almost constant pain, and occasional delirium in the second story front room of his residence, 2102 Pine street, Philadelphia, on a bed which scarcely found a place among the heaps of specimens and publications which filled every available floor space. During one of his delirious periods he delivered a most interesting and vivid lecture on the Felidae, with all his charm of manner and diction, and all his profound knowledge of the history of the subject, the discoveries up to date, and their relations to each other and to other great problems of zoology. It is said to have been such a discourse as would have made the reputation of a perfectly unknown lecturer in the most learned assembly, but, alas, it was the flickering of the candle before its final extinguishment.

In 1897, and the following year, thirty scientific papers by Prof. Cope were published.

The following are selected from numerous manuscripts, some unfinished, left by Prof. Cope. They date from very different epochs of his life, and most of them appear to have been unpublished, though some were doubtless used as addresses or discourses. They are partly brief, abbreviated memoranda, jotted down as they occurred to him and intended for future elaboration.

"In imperfect and early conditions of man, the same difference between the two masters of the affections existed. In execution, difference of knowledge of the Divine goodness would produce diff. results in practical morals. As man's ideas of God are anthropomorphic, so his ideas of Divine will largely depend on his knowledge."

"Knowledge of right has always been far enough ahead of practice to render it a guide."

Theology.

(A) Facts.

"Existence and inheritance of Evil—Evolution physical and metaphysical: Intellect.: knowledge.: judgment, Affections, Love, Hate.

Knowledge insufficient to influence will.

Affections for right necessary. Christ's personal influence

when on earth, e. g. John, Luke, Matthew, Nathaniel,—left all.

The paraclete causes development of affections in his stead.

Hence will affected to execute."

(B) Doctrine.

"Hence substitutionary doctrine unnecessary; and inconsistent with common sense.

Hence Justification (preached by John Baptist before Christ), is not the same as Calvinism. Hence Paul was affected by Judaism and plenary inspiration is not credible."

"Intellect not the source of Springs of Life, but the channel through which the streams are to flow."

"Many men have potential goodness which does not become energetic."

"Might as well expect the Lord to stop digestion because we do not understand its philosophy as work of religion because we do not understand doctrine."

"Does force or motion give shape to the atoms and so constitute them different species of matter (simple substances), or

"Did the forms of atoms appear first and divide the species of force from each other?"

"Less to be accounted for in first case than the last, because it predicates only vibrations and round atoms—2nd vibrations and angular or many sided atoms.

"Hence force in different degrees created types of matter."

"So higher forms of force overcome always lower: (1) gross motion is converted into heat (by friction or impact). (2) Heat into chemism (by chem. union under rise of temperature), (3) Heat into electricity. (4) Chemism into electricity (in battery).

"Force creates machinery by changing shape of atoms which thus are capable of new kinds of conversion. Thus it created phosphorus which is a machine for evolving light when uniting with oxygen; protoplasm (by chemism) wh. is a machine for converting heat, etc., into motion; w. design i. e. life."

"It remains to be seen which is fittest to survive; the intellectual type, the religious, or the economic. No doubt each

estimates a man by its own standard; the intell. for his intel. products; the religious for his fervor or good works; the econom. for his possessions. But the intell. will die of unbel. and despair, the economic of losses and combats, the religious only can survive because it carries the hope of Faith."

"How much more readily men hunt in packs, than singly. shows that the wolf is not yet banished from our nature. Each grade of men hunts according to his level; the lower after those who commit offences against person and property; another class those who have violated the rules of social observance; the religious world against what they suppose to be (often erroneously) false doctrine."

"If the devil is let loose for a thousand years it will not be the fault of the truth, but of those who abuse it. Just as civilization vanished so soon as Christian mercy took the place of heathen intellect through the abuse of it, by rulers and people. And the gospel of evolution is a new gift of the love of God to man; may he not abuse it as of old."

"We may perceive by logical succession in five minutes what ages of experiment have cost."

"There is a time when motives have their origin in a state of indifference to the matter in question; then we originate a motive by attention to knowledge.: then free-will enters."

Of consciousness.

"Creation, the perpetual astonishment of the universe to all ages."

In 1870-71, on becoming a member of the A. N. S., of Philadelphia, the present writer first made the acquaintance of the subject of this sketch, and formed a friendship with him that lasted till that sad April morning in 1897, which deprived American science of one of its most brilliant ornaments. This friendship grew rapidly in the years immediately following its inception, owing to certain controversies in the A. N. S. and the American Philosophical Society wherein it appeared to the writer that Cope was the victim of injustice.

For many years before the death of the present writer's father, Prof. John F. Frazer, in 1872, the informal Sunday evening meetings at his house of some of

the scientific and literary men of Philadelphia, and especially of those passing through the city, had become fixtures widely known to the classes above referred to. The late Dr. John L. Leconte, Prof. J. P. Lesley, Mr. Winsor, Prof. Fairman Rogers and others, were constant visitors as Philadelphians while Profs. A. D. Bache, Louis Agassiz, Joseph Henry, Benjamin Peirce, Benjamin A. Gould, Alexander and many others never failed to attend when in this city. After the death of Prof. John F. Frazer, Oct. 12, 1872, the Sunday evening gatherings were continued by his son, and among those who were most regular in attendance were Edward D. Cope, F. V. Hayden, and Admiral E. Y. McCauley, (all now deceased). Up to his last illness, with rare intervals, professor Cope was the most constant of all, and usually discussed the subjects which were at the time engrossing his attention in his liberal, learned, and broad-minded manner. Very frequently on these occasions his eloquence and force were extraordinary, and the clear statement of his position on each question, with the arguments in support of it, were inspiring to his listeners. It was noticeable that the reasons which he urged in support of a proposition were always of a high and impersonal character, without regard to his own or any other individual interests. No man could have been more just to the rights of others, no matter what his private relations with them were. In this respect he showed a true scientific (judicial) mind of the highest order, and a power of eliminating selfish considerations from his reasoning which is as rare as it is worthy of imitation. Occasionally the turn of the conversation would draw from him one of his characteristic summaries or generalizations of subjects within his own special lines of research, and at such times his rapid and accurate memory of the complex facts in the history of each subject, and his unerringly correct use of the constantly multiplying names of classes, orders, genera, species, and varieties, (a faculty which won the admiration of his great predecessor, Joseph Leidy) were amazing.

Not less remarkable was his faculty of appreciating the full value, often unknown to the speakers themselves, of whatever was said to him, and his instantaneous incorporation into his system of philosophy of such hints when valuable.

But a defect, which he recognized, was a tendency to be in-

fluenced, and sometimes severely pained by a misinterpretation of what had been long before said to him, and at the time unnoticed by him. He used to say "I take a long time to get mad," but this does not quite express the fact. In the course of an animated conversation he enjoyed being opposed by logical argument, which only sharpened his mental faculties. The defect was that long subsequently and when in a different mood, he recalled the words without the accompanying circumstances; and thought he was remembering all; while a temporary morbidity invested these words with a meaning entirely different from what was intended, or what could have been understood when they were uttered. This weakness naturally increased with his years, and frequently precipitated acrimonious controversies at particularly inopportune times with persons who had the power to do him great injury. In his earlier years, his forbearance, in some cases of wanton and unmerited attack, was a matter of surprise to his friends. He would frequently say, "I am too busy to get angry. While —— is abusing me, I am getting through lots of important work." Had he been able to retain this power of self control throughout his life, when his eminence became incontestable, he would have accomplished even more than he did—marvelous as that is—and with a great deal less difficulty and mental suffering, but he would not have been the Cope we have known.

His capacity for work, was, at all periods of his life, prodigious though his methods were peculiar to himself and like those of some of the strongest prosecutors of original research erratic. When asked in the early eighties how he could get through such an enormous amount of diversified labor, he replied: "By eschewing liquor and tobacco and minimizing nervous storms."

Within the ten years he began the moderate use of both liquor and cigars, but he used them sparingly, as aids to digestion, or sedatives, rather than convivially or as stimulants.

With excellent capacity to understand any subject whatever, he was, like many scientific men, inexperienced in business affairs, and what is called knowledge of the world. On the death of his father, he was struggling, with the aid of a very scanty allowance, to carry on extensive field operations for several great scientific exploring expeditions, (Wheeler's,

Hayden's, and several special expeditions); to maintain several collecting parties of his own in distant fields on this and other continents; to prepare his reports on the collections thus obtained; and to contribute largely to the scientific and popular magazines. With the inheritance of more than a quarter of a million of dollars it never occurred to him to seek a life of ease, nor even to invest this fortune securely and use the income judiciously in behalf of the enterprises in which he was engaged. He immediately conceived the idea of investing it in a manner to procure much larger returns, all of which he would utilize in investigations of pure science. With child-like confidence he accepted the statements of glowing prospectuses and interested promoters, and scattered his capital in many directions on insecure guarantees, where he had neither the time nor the ability to guard it. In consequence of this he was almost immediately confronted with losses which alarmed and confused him. Instead of accepting these as severe warnings that he was entering upon unknown dangers, and withdrawing on the best terms available, with a diminished but still handsome fortune, he plunged deeper into these investments and lost so heavily that his whole subsequent life was harassed, and even the moderate requirements of himself and his family inadequately met. Add to this, and to the embittered warfare with those who should have shown him more consideration, a series of misfortunes with successive publishers of the American Naturalist, a journal, which he had bought and brought down from Salem, Mass., to Philadelphia, misfortunes which no one could have foreseen; and the wonder grows that in the last two years of his useful life he should have been able to produce a tithe of what his record shows; or indeed, that he should have been able to survive these multiplied worries and cares.

In spite of all, however, he persisted in a rugged and vigorous health, broken by attacks of gradually increasing frequency, involving intense pain and much exhaustion, and lasting from one to three weeks at a time. Nevertheless, his natural buoyancy of spirits, and his optimism carried him through them all till the last one which proved fatal.

Even during this last sickness he confidently believed he would recover and had made plans for the immediate future,

as soon as he should be able to get into the fresh air of the country, and face to face with Nature, which he so dearly loved from his earliest childhood. In his letter to his aunt, the last he wrote, and only two weeks before his death, one sees this optimism. He does not propose to die just yet, looks upon health as the greatest of blessings, is glad that so many possess it; thinks the enforced break in trying occupations turns one's thoughts to other and necessary subjects, and is prepared to die—when the time comes—in the settled conviction that it will be a change for the better. This letter is a touching and fitting farewell of a great mind to a world in which he had accomplished a gigantic work.

Among the biographies and the bibliographies of Cope may be mentioned—

"The literature of Prof. Edward D. Cope," by Hosea Ballou. The Chicago Field, Aug. 21 and 28, 1880; and the sketch of his life in the Germantown (Philadelphia) Independent, Aug. 30, 1884, both printed during his life, and probably with his assistance.

Marcus Benjamin, "Science" (?), Aug. 22, 1896.

J. S. Kingsley and Persifor Frazer, in the American Naturalist, Vol. XXXI, No. 365, May, 1897.

Prof. Henry F. Osborn. The Century Magazine, November, 1897.

Idem, The American Naturalist, December. 1897. "Trituberculy."

Idem, Science, May, 1897.

Miss Helen Dean King, biography with bibliography. American Geologist, January, 1899.

Bulletin de la Société géologique de France; tome 26, p. 290.

Sitzungsberichte der math. phys. Classe der k. b.

Akademie der Wissenschaften zu München; Heft. 3, p. 487, 1898.

Among the honors bestowed upon him were the following: Membership in the National Academy of Science of the United States in 1872. The Bigsby gold medal from the Geological Society of London in 1879. The Hayden memorial medal in 1891. Membership in the Imperial Society of Moscow in 1886. The degree of Ph. D. on the occasion of the 500th anniversary of the foundation of the University of Heidelberg in 1886. Professorship of Geology in the University of Pennsylvania in 1889.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Ami, Henry M.

Sir John William Dawson, a brief biographical sketch [Portrait]. (Amer. Geol., vol. 26, pp. 1-48, July, 1900.)

Blake, Wm. P.

Glacial erosion and origin of the Yosemite valley. (Trans. Am. Inst. Min. Eng., Sept. 1899.)

Blatchley, W. S.

Department of Geology and Natural Resources, 24th Annual Report, [Indiana]. Indianapolis, 1900.

Blatchley, W. S.

The natural resources of Indiana. (24th Rep. Dept. Geol. Nat. Resources, pp. 3-40, 1900.)

Dawson, Geo. M.

Economic minerals of Canada, pp. 54, map. (Paris International Exposition, 1900.)

Eastman. C. R.

Devonische Fischreste aus der Eifel. (Am. Geol., vol. 25, pp. 391-392, 1900.)

Emerson, B. K.

Carboniferous bowlders from India. (Am. Jour. Sci.. vol. 10, p. 57, July, 1900.)

Emerson, B. K.

New bivalve from the Connecticut river Trias. (Am. Jour. Sci. vol. 10, p. 58, July, 1900).

Faribault, E. R.

The gold measures of Nova Scotia., pp. 40, Halifax, N. S., 1900.

Fisher, C. A.

Geology of Lincoln, [Nebraska] and environs. (The Grad. Bull. Univ. Neb., vol. 1, pp. 35-41, plates, 1900.)

Foerste, A. F.

A general discussion of the middle Silurian rocks of the Cincinnati anticlinal region, with their synonymy. (24th Report, Indiana Dept. Geol. and Nat. Res., pp. 40-80, 1900.)

Foerste, A. F. (N. S. Shaler, J. B. Woodworth and)

Geology of the Narragansett basin. Mon. 33, U. S. G. S., pp. xx, 394, pls. 31, 1899.

Fuller, M. L.

An instance of subaqueous differential weathering. (Am. Geol. vol. 25, pp. 355-360, June, 1900).

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology, and mineralogy.

Gilbert, G. K.

Rhythms and Geologic time. (Science, N. S., vol. 11, pp. 1001-1012, June 29, 1900.)

Girty, G. H.

Devonian and Carboniferous fossils, [Yel. Nat. Park.] (Mon. 32, Part 2, pp. 580-599, pls. 66-71, 1899.)

Gould, C. N.

Non-conformities at the mouth of the Platte river. (Am. Geol., vol. 25, pp. 364-369, June, 1900.)

Gregory, H. E.

Volcanic rocks from Temiscouata lake, Quebec. (Am. Jour. Sci., vol. 10, pp. 1-14, July, 1900.)

Gresley, W. S.

Possible new coal plants in coal. Part II. (Am. Geol. vol. 26, pp. 49-55, 4 plates, July, 1900.)

Hague, Arnold,

Descriptive geology of Huckleberry mountain and Big Game ridge. (Mon. 32, Part 2, U. S. G. S., pp. 165-203, pls. 24-26, 1899.)

Herrick, C. L.

Report of a geological reconnoissance in western Socorro and Valencia counties, New Mexico. (Am. Geol., vol. 25, pp. 331-346, 2 pls.. June, 1900.)

Hershey, O. H.

The upland loess of Missouri—its mode of formation. (Am. Geol., vol. 25, pp. 369-374, June, 1900.)

Hovey, E. O.

Oliver Payson Hubbard [Portrait.] (Am. Geol., vol. 25, pp. 360-364, June, 1900.)

Hovey, E. O.

The Wind cave of South Dakota. (Sci. Am. Sup., June 16, 1900.)

Iddings, J. P., and W. H. Weed.

Descriptive geology of the northern end of the Teton range. (Mon. 32, Part 2, U. S. G. S., pp. 149-165, pl. 23, 1899.)

Iddings, J. P.

The igneous rocks of Electric peak and Sepulchre mountain. (Mon. 32, Part 2, U. S. Geol. Sur., pp. 89-149, pls. 12-22, 1899.)

Iddings, J. P.

The igneous rocks of the Absaroka range and Two Ocean plateau, and of outlying portions of the Yellowstone National Park. (Mon. 32, Part 2, U. S. G. S., pp. 269-325, pls. 35-36, 1899.)

Iddings, J. P.

Absarokite-Shoshonite-Banakite series [Yellowstone Nat. Park]. (Mon. 32, Part 2, pp. 326-355, pls. 37-38, 1899.)

Iddings, J. P.

Recent basalts [Yel. Nat. Park]. (Mon. 32, Part 2, pp. 433-439, pl, 59, 1899.)

Iddings, J. P., (and W. H. Weed.)
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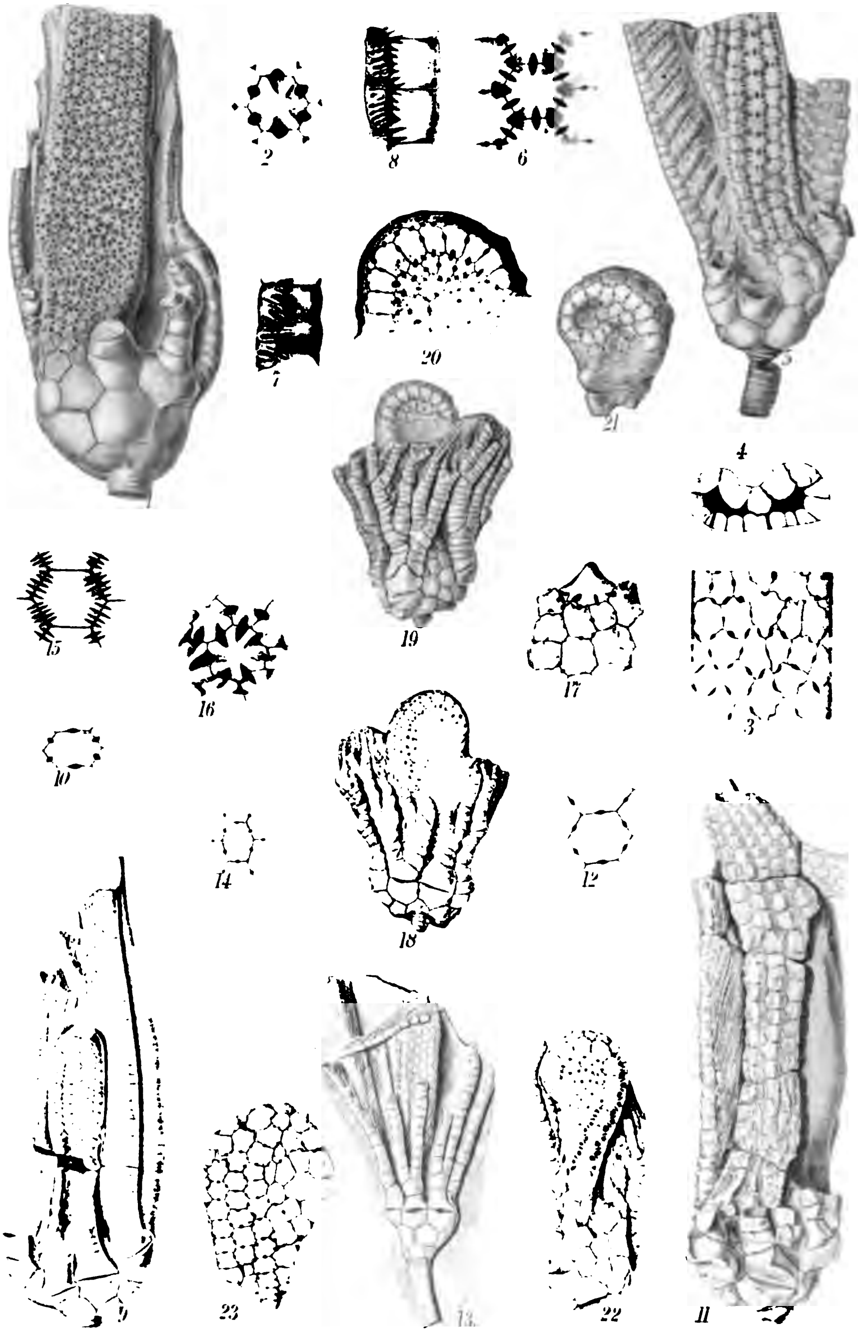

F. SPRINGER ON CRINOIDS

THE

AMERICAN GEOLOGIST.

VOL. XXVI. SEPTEMBER, 1900. No. 3

ON THE PRESENCE OF PORES IN THE VENTRAL SAC IN FISTULATE CRINOIDS.

By FRANK SPRINGER, East Las Vegas, N. M.

(Plate XVI.)

At various places in the works of Wachsmuth and Springer the statement has been made that the ventral sac of certain fistulate crinoids was pierced by pores, slits, or fissures, which penetrated to the interior of the sac.*

This has been criticised by Mr. Bather, and the existence of such pores or fissures denied as to *Cyathocrinus*,† *Thenarocrinus*,‡ and *Botryocrinus*.§

In our Monograph of the Crinoidea Camerata we reiterated the statement as to some Fistulata, saying that in the Fistulata the sac was often perforated by pores (p. 114). In a note on the same page we made a more definite statement as follows:—

"Mr. Bather is of the opinion that the ventral sac of the Fistulata is not perforated, but only pitted. . . . This may be true as to *Cyathocrinus*, *Euspirocrinus*, and possibly the Cyathocrinidæ generally, in which very likely the madreporite performed the functions of the tube-pores; but we have

*Revision of the Palæocrinoidea, III, pp. 66, 83.
Perisomic Plates of the Crinoids, Proc. Acad. Nat. Sci. Phil., 1890, p. 361.

†British Fossil Crinoids, I, p. 311; Ibid, VIII, pp. 212, 220, 224.

‡*Ibid*, III, p. 229.

§*Ibid*, V. pp. 407, 408; and Crinoidea of Gotland I, p. 122.

the most complete evidence that among the Poteriocrinidæ, in many cases, the pores pass through the test."

In support of this statement, we gave figures on Plate VII, viz., figs. 2, 5, 7, 8, 9 and 10.

Commenting on the foregoing statement, and the figures of actual specimens given by us, Mr. Bather, in his review of our Monograph,* denies the accuracy of our figures, and expresses the opinion that the artist would not have drawn figures 5 and 9 as they appear, if he had not been told to put in structures which he could not see. His commentary on this subject in full is as follows:

"Wachsmuth and Springer now admit my statement for '*Cyathocrinus*, *Euspirocrinus*, and possibly the Cyathocrinidæ generally, in which very likely the madreporite performed the functions of the tube-pores'; but they 'have the most complete evidence that among the Poteriocrinidæ, in many cases, the pores pass through the test.' Perhaps they have. And yet I am still sceptical. It was examination of *Scaphiocrinus multiplex* itself, the first and chief species in which such pores were observed, that made me doubt the observation. I have examined, with like result, specimens described and figured by Grenfell and by Lovén. Now, let the impartial reader compare my detailed descriptions and the drawings by Liljevall, Hollick, and myself, magnified 8, 16 and 20 diameters, with the bald statements and drawings, scarcely more than natural size, published by Wachsmuth and Springer. He will admit that scepticism is justified.. Nay, more, let him examine two of the figures on which they specially rely, namely, pl. vii, figs. 5 and 9. He will observe that the supposed pores are drawn in the middle of each side of each hexagonal plate of the tube; each pore lies on a line passing between the centers of adjacent hexagonal plates. Then let him look at the other figures, such as 2b, and he will note that the supposed pores are at the angles of the plates, and never on the radial lines. Let him then examine a few hundred specimens of fistulate genera, and he will find that the apparent pores or slits never are on the radial lines, but always at the angles or between the ridges of the folded plates. Some re-

*Geological Magazine, Dec. IV, vol. V, 1898, Nov., p. 526.

semblance to the alleged structure of *Aulocrinus* is presented by *Gissocrinus verrucosus*,* but this is only partial and superficial. I do not accuse the authors of any intention to mislead, but this I do suggest; that their artist would not have drawn figures 5 and 9 in this way had he not been told to put in structures which he really had a difficulty in seeing. Few scientific writers have not had a like unfortunate experience. If *Aulocrinus* truly has a ventral sac of this nature, it differs far more from other Fistulata than Messrs. Wachsmuth and Springer have stated. If the structure is correctly drawn it is most extraordinary that it should not be specially mentioned in the text. But it is so opposed to all facts hitherto observed or published that, until Mr. Springer himself compares fig. 9 of pl. vii with the original specimen, and assures us publicly that the pores have the position there assigned to them, and gives a properly enlarged drawing or photograph in support of his statement, scepticism will be more than justified."

Later on, in the chapter on Crinoidea written by Mr. Bather for Ray-Lankester's Treatise on Zoology—of which he was kind enough to send me advance sheets—chap. XI, p. 130, Mr. Bather makes a rather sarcastic allusion to these same figures, as follows:—

"The statement has repeatedly been made (by Trautschold, Lovén, Wachsmuth and Springer) that pores occur on the suture lines between the plates composing the anal tube of many Inadunata. . . The statement has been definitely disproved for many forms hitherto said to have such pores. But Wachsmuth and Springer (1897, pl. vii, figs. 2b, 5, 6, 9) support it by figures which, if correct and correctly interpreted, prove it for some species up to the hilt—and much farther. For they show pores not only on the sutures, but penetrating the plates; not only in the interaxial depressions, but on the axial folds; not only in the tube, but in the dorsal cup."

Now, criticism is one thing—and so long as it keeps

*Crinoidea of Gotland, I, pl. x, fig. 378; Svensk. Vetensk, Akad. Handl., xxv, 2, (1893).

within its legitimate bounds I am not restive under it. Our theories, opinions and conclusions, however promising they may seem to-day, are liable to fall to the ground to-morrow, by reason of the discovery of new facts. Our judgment may be wrong, our methods faulty, and our interpretation of facts erroneous, or they may differ from those of others—and as to all these matters we must expect opposition and criticism. I, for one, am always ready to receive them with equanimity, and consider them without resentment. In the very extended review with which Mr. Bather has honored our work, I am ready to frankly admit that several of his objections are well taken, and most of them are worthy of the greatest consideration. Upon some of the disputed matters of opinion we shall continue to differ, and as to some I think he has probably gotten nearer the truth than we. As each careful student has the benefit of the labors of his predecessors, which he may utilize from new points of view, and supplement with fresh observations of his own, it is to be expected that the latest investigator should make substantial advances upon the works of those before him. This is not the place to consider any of these questions, and I have no intention of reviewing our reviewer.

But accusation of misrepresentation of facts is a very different thing, and calls for a direct reply. It should have been given before now, but for the impossibility—owing to press of other duties—of preparing it, and having the necessary illustrations made. The charge against us is a very serious one, for if true it may well deprive our Monograph—which contains the results of twenty years labor—of all claims to recognition among scientific men, as a trustworthy record of the facts it professes to set forth. It is true Mr. Bather says that he does not accuse us of an intention to mislead. But the kind of accusation which does not accuse, I do not understand. And I am very sure that if any one should put in print for general circulation such a statement as the one above quoted touching any work of his, Mr. Bather would consider it the most deadly of accusations.

The questions to be settled are two:

1. Are the figures in the Monograph correct?

2. Are there pores piercing the ventral sac in certain Fistulata?

Mr. Bather's proposition is that the structures which we have represented as pores do not penetrate the plates at all. He agrees that there are certain pits or depressions that superficially may resemble pores or fissures, but claims that in certain species of *Cyathocrinus* and allied genera, he has by cleaning away the matrix exposed the actual surface of the plates at the bottom of these pits, and found that the sutures are continuous across them, and not interrupted by pores or fissures. He disbelieves, to the extent of avowed scepticism as to the reliability of our proofs, that it can be otherwise in other forms. He thinks that we have mistaken for pores depressions which exist at the corners of the plates, as he found them; and because we figured specimens in which the depressions appear to be situated elsewhere than at the corners of the plates, he concludes that we have caused the artist to show structures which do not exist. For evidence in favor of his opinion he refers to our fig. 2b (pl. vii) as showing that the pores are at the angles of the plates, and never on the radial lines. The "impartial reader," on examining this figure, will observe that out of about 33 pores shown, 12 are at the middle of the sides, 16 at the angles, and 5 at neither, but on the plate itself. The fact is that those at the sides, or on the "radial lines," as Bather calls it, are the only correct ones. A careful examination of the specimen under a magnifier shows this. The apparent position of most of the others is deceptive, owing to the manner in which the specimen is crushed. The artist was not to blame for this, for so far from being told to put in structures which he could not see, sufficient care was not taken, in this instance, to see that the specimen was placed for drawing so as to show the pores only in their absolutely correct position. In the specimen figured the preservation was such that the pores were not readily seen at all, on account of a superficial limestone deposit which partially obscured them. Besides this, the sac was longitudinally fractured and folded on itself so that some of the pores appeared in a different relative position from the correct one. I have carefully cleaned both the original of fig. 2b, and another specimen of the same species. It is perfectly plain in the original, by holding it in different positions toward the light, which cannot be done in the drawing, that all the pores are

on the radial lines, and none of them at the angles. I have given a figure of the other specimen, which shows the structure much better, natural size, and one plate with parts of contiguous ones, enlarged 4 diameters (Pl. XVI, figs. 9, 10). I have three other specimens of this species which show the same structure.

After having referred to our figure 2b for the correct position of the supposed pores, Mr. Bather next invites the impartial reader to "examine a few hundred specimens of fistulate genera, and he will find that the apparent pores or slits never are on the radial lines, but always at the angles or between the ridges of the folded plates." Where such wealth of material is to be found, to enable the student to examine specimens of fistulate genera preserving the ventral sac by the few hundreds, I do not know. The Wachsmuth and Springer collection has been supposed to be pretty well provided with structural specimens, culled from the largest collections ever made at the best localities for this purpose, but I cannot lay claim to such multitudes. I must be content to number those exhibiting the parts in question only by the dozens. They are sufficient, however, to show about all that can be expected to be shown by fossils. Upon the evidence of abundant and sufficient material at my command I am compelled to dispute the correctness of the above statement *in toto*. That the depressions found by Mr. Bather in certain Cyathocrinidæ, and figured by him (Crinoidea of Gotland, I, pl. vi, fig. 190, and text fig. 17, (2) p. 119, and elsewhere) lie at the angles of the plates, I have no doubt. But as to the structures which have been described by Wachsmuth and Springer as pores or fissures passing through the test in the Poteriocrinidæ, I can state without fear of further contradiction that in the large number of cases where I have observed them, the rule is without exception that the position of the pores is the exact reverse of that stated by Mr. Bather.

They are always "*on the radial lines*," *i. e.*, in the middle of the sides of the hexagonal plates, and never at "the angles of the plates." This statement I will substantiate by evidence which I think will be satisfactory to all naturalists.

The illustrations accompanying this paper are from drawings made with extreme care by an experienced artist, Mr. J.

Henry Blake, of Cambridge, Massachusetts, and may be relied upon as accurate, so far as human skill and care can make them so. In addition to the enlargements noted for the different figures, the whole plate was drawn twice the size it now appears, and reduced by the Heliotype Company to its present size by photography.

1. *Are the Figures Correct?*

The charge of misrepresentation is based especially upon figures 5 and 9 of Plate VII, of the Monograph of the Crinoidea Camerata. I will consider them, as well as the others, in detail.

Fig. 5. (*Decadocrinus tumidulus*) M. and G. (figured by us as *D. grandis*). This figure only shows a small number of pores in the upper part of the ventral sac. They are correctly placed as far as they go, except one or two, which by inadvertence, and from not having his attention specially called to it, the artist erroneously represented as at the angles of the plates. But in order to show the fact more clearly I have figured another specimen of the same species, which shows the pores much better, together with an enlarged figure of one plate and adjacent parts of others (Pl. XVI, figs. 5, 6). The pores are very large and prominent. They are for the most part, especially in the median row of plates, elongate, crossing the sutures at right angles to the middle of the sides, elliptic (lozenge shaped); and they extend well in from the suture to the substance of the plate. They are not all of this shape, although all are in the same position at the middle of the sides of the hexagonal plates;—some of them are round. If the other described specimens are not sufficient, this one affords the most absolute proof that the pores are not mere surface depressions at the angles of the plates;—for here not only do they lie at the middle of the sides of the hexagonal plates, "on the radial lines," but they actually lie in the ridges which pass from plate to plate, instead of between them. This is rather exceptional, for usually where there is a stellate ornamentation, the ridges pass from plate to plate across the angles, and the pores are situated between them; but here both pores and ridges cross the sides of the plates and neither of them the angles. Five other specimens of this species show the same structure.

Fig. 9, *Aulocrinus agassizi.* This figure was drawn by Mr. Westergren from a splendid specimen—perhaps the finest of this extraordinary form. It was found and cleaned by myself. The structure being unusual, and, I not knowing what to expect, the part of the ventral sac exposed by the breaking off of some of the arms was freed from the adherent matrix under a magnifier. While doing so I observed the pores throughout almost the whole length of the sac, and the pipe-like anal tube as well, located at the middle of the sides of each hexagonal plate. Mr. Westergren was instructed to draw the pores in his figure, but they were so plain that it was not necessary to give him any special directions as to their position. Whatever may be the theoretical reasons why it should not be so, his drawing is absolutely correct. Four other specimens of this species show the pores, with perfect distinctness, in the same position. As this figure is the main point of attack, I have had Mr. Blake make a very careful drawing from another specimen, which has lost the anal tube, but which shows the pores in the sac almost as well as the former one. This is made natural size (Pl. XVI, fig. 11), and he has also drawn one plate and parts of adjoining ones, enlarged 4 diameters (Pl. XVI, fig. 12). From these it will be seen, beyond the slightest doubt, that the pores invariably occupy the middle of the sides of the hexagonal plates—exactly where Mr. Bather says they are never found. The surface of this sac is conspicuously marked with nodes, which occupy the middle of the plates. The pores, although not of large size, are readily observable without a glass, being filled with a dark infiltrated matrix different in color from the substance of the plate.

I have no doubt that Mr. Bather, impelled by the result of the minute study of certain English and Swedish specimens of Cyathocrinidæ, became thoroughly convinced that his understanding of these structures was the only correct one—not only for the specimens in which he had seen them, but for all others. A notion once deeply rooted in the mind is not easily eradicated, and it is the "unfortunate experience" of most of us that it often influences not only our judgment, but our observation also, so that we see things not as they are, but as we think they ought to be. Mr. Bather would no

doubt readily admit the truth of this observation as applied to Messrs. Wachsmuth and Springer. But in view of the gravity of the charge he has made against the truthfulness of our work, and in order to show that the above remark is applicable to others besides ourselves, I think it only fair to state that Mr. Bather, before he wrote his criticism, and before our work was published, had himself seen and examined all of our specimens of *Aulocrinus*, including the original of fig. 9, pl. vii. And I have no doubt that when he charged us with giving an erroneous figure of this specimen, he did so in the full belief that he had seen the structures in question to exist in this very specimen contrary to our representation of them, but consonant with his opinion of how they ought to be.

Mr. Bather thinks it extraordinary, if *Aulocrinus* has a ventral sac perforated as we have figured it, that we should not have specially mentioned it in the text, as he thinks it would in that event differ far more from other Fistulata than we have stated. After examining the figures I have prepared to illustrate this paper, he will doubtless agree with me that it was not necessary to make special mention of differences which do not exist.

Figs. 2a and b, *Scytalocrinus validus*. I have already given a sufficient account of this figure, which was partly incorrect, on account of a longitudinal fold in the sac, but in which the chief error consisted in locating the pores as Mr. Bather says they should be, and not as they actually are. The new figure here given, with enlargement of one plate 4 diameters, is from a very perfect specimen, which shows the pores with absolute distinctness, at the middle of the sides, and not at the angles. They are small as in the preceding species, but as in that are well distinguished by being filled with a matrix darker than the plates. The surface of the plates is simply granular, without any ornamentation whatever (Pl. XVI, figs. 9 and 19).

Figs. 4, 6, 7, 8:—These are not specially disputed, although they necessarily fall under the same general condemnation. It is figure 6, *Scaphiocrinus unicus*, to which Mr. Bather doubtless alludes in the Lankester Treatise on Zoology when he says "they show pores . . . not only in the

tube, but in the dorsal cup." The specimen from which this figure was made came from Crawfordsville, Indiana, and both the test and matrix are dark, so that it is very difficult to interpret the minute structures. The pits to which he alludes as pores piercing the dorsal cup are very deep depressions at the angles of some of the plates. Whether they actually pass through the test I cannot tell from the specimen, and I do not profess to give any explanation of them. I may here remark generally that the pores are not always to be seen in specimens preserving the ventral sac, for two reasons. (1) The condition of fossilization. There is a great difference in specimens from different localities. The Crawfordsville specimens, which are oftener seen in collections than any others in which these parts are preserved, generally have the substance of the plates dark colored, and of a rather rough granular structure. In these it is difficult to detect or draw the fine structures, because there is no contrast between the test and the matter with which the pores or other cavities were filled. Little is to be gained in these cases by grinding, scraping or cutting—as I have learned to my cost. In specimens from Indian Creek, and from Huntsville, the test is of a finer and firmer texture, and of lighter color than the infiltrating matter, so that all cavities are well shown by the contrast, and the surface of the plates can be accurately cleaned, by both mechanical and chemical means. (2) The pores do not as a rule—probably never—occur throughout the entire sac, but are confined to limited areas. As we usually see but one side of the sac in the fossil state, we may often miss them for this reason.

Referring again to our figure 6, the specimen figured did not show any pores in the sac. The species is found both at Crawfordsville and Indian Creek in excellent preservation—especially at the latter locality. Several specimens show the ventral sac; but the sac is one of those which are covered with a very deep sculpturing, which has made it difficult to distinguish pores from mere depressions, such as Mr. Bather found in his specimens of *Cyathocrinus* and *Botryocrinus*. I have now ascertained that the pores are present in this species also, and are located on the radial lines. They are quite small for the size of the specimens, and lie, not in the grooves

which pass from plate to plate and which run to the angles, but in the ridges between them which cross the middle of the sides of the plates—as in *Decadocrinus tumidulus.* This is best shown where some plates are turned up on edge, and the small pore channels can be seen following the ridges across the edge from the exterior to the interior surface, two to each plate. An enlarged view of such plates is here given in figure 7, of Pl. XVI.

As to Fig. 7, *Scytalocrinus* (sp. undet.), I do not deem it necessary to refigure this specimen, as it would result in producing a duplicate of Mr. Westergren's original drawing. By changing the position of the specimen with reference to the light, slight differences might be produced. But this would not alter the fact that the pores are located at the middle of the sides in depressions between the stellate projections which run to the angles of the plates—a structure which is still more plainly shown in the next figure—fig. 8. I have no other specimen of this species showing the ventral sac.

Fig. 8, *Scaphiocrinus swallovi,* was drawn from a specimen from the Burlington limestone, in which the plates are very perfectly freed from the matrix, which in this case was an extremely fine, soft, yellow, sandy clay, and was removed with a soft brush and wetting—leaving the white substance of the plates as free as those of a living specimen where the soft parts have been dissolved by potash. The apertures at the middle of the sides of the hexagonal plates are entirely free and open, so that a needle can be passed through many of them. They are located in elongate depressions which pass from plate to plate on the radial lines, the angles of the plates being traversed by ridges. The pores are perfectly open in the fossil, forming a channel across the edge of each side of the plate at the middle—cut half out of each plate—so that the two in apposition form a more or less circular opening. There can be no question here as to whether these depressions pass through the plate, for we have the edge of the plate, free of all matrix, actually cut away to its full thickness. A single plate, by reason of these rounded notches on the sides, becomes hexagonally stellate. In order to show this more plainly, I give an enlarged figure of one of these plates and

its connections with adjacent plates, from the same specimen (Pl. XVI, fig. 16).

Fig. 4, *Decadocrinus grandis* W. & Sp., shows a few pores at the sides of the hexagonal plates in the sac. Many more might have been shown if a specimen had been selected with special reference to them, for they are more or less plainly visible in eleven specimens in my possession. I have figured the distal portion of the sac in one of them, showing the pores at the middle of the sides of the plates. (Pl. XVI, fig. 17).

2. *Are there Pores piercing the Sac in certain Fistulata?*

The facts already given in confirmation of the figures and statements contained in our Monograph would seem to be sufficient to settle this question in the affirmative. But this is by no means all the evidence at my command, and I will give some additional proof which will be convincing to all students, including, I think, Mr. Bather himself.

In the first place, I wish to illustrate a form of apparent apertures in the sac, somewhat different from most of the preceding ones, viz.: elongate fissures. These are best shown in the upper part of the sac in *Scaphiocrinus missouriensis*, from the St. Louis limestone. We figured the lower part of a specimen of this species (Monog. Pl. VII, figs. 1a, b) for the purpose of showing the location of the anal opening. I give an enlarged figure (Pl. XVI, fig. 15) of a plate and connections, from the sac of another specimen. It will be observed that these plates do not have distinct pores at the sides, but narrow parallel fissures passing from one plate to another, crossing the sutures at right angles, and at the middle of the sides—not at the angles. These fissures are not a mere surface ornamentation, but in this specimen are filled with a substance darker than the test, just like that which fills the pores in the other specimens. Upon a careful examination of a number of specimens, with a strong magnifier and good light, I am convinced that these fissures do actually penetrate through the plates to the interior. There is a depression at the side of each plate, it is true, toward the suture, but the fissures cross the depressions and extend nearly to the middle of the plates. The plates at this part are extreme-

ly thin, so that no aid can be had by grinding on any of the specimens I have. I have a specimen, however, in which the ventral sac, crushed flat, is free on both sides. The fissures seem to have been filled with a matrix the same color as the test. At the depressions toward the sides of the plates the sac is as thin as tissue paper, and when seen by transmitted light the fissures show as bright lines, as if they were actually open slits.

Scytalocrinus hoveyi, from the Keokuk limestone of Crawfordsville, has a sac of hexagonal plates which are crossed by fissures similar to those of *Scaphiocrinus missouriensis*, only in this species the plates are somewhat thicker. In one of my specimens, near the distal end of the sac, the edges of several plates are turned up and exposed to view. These show with the greatest distinctness that the fissures pass over the edge of the plates and run to the interior. Fig. 8 of Pl. XVI, which is an enlarged view of some of these plates, shows this perfectly. The fissures cross at the middle of the sides, not at the angles.

It is not upon these specimens with elongate fissures, however, that I place the chief reliance, but upon specimens of additional species in which the ventral sac is either perfectly smooth, or can be made so by grinding off the surface, and which have well defined pores passing through the test, on the radial lines.

The first of these is *Scytalocrinus van hornei* Worthen, from the St. Louis limestone (Pl. XVI, figs. 13, 14). In this the surface of the sac is perfectly smooth, unmarked by ridges or depressions of any kind. The pores are darker colored than the substance of the test, and appear distinct on the radial lines at the middle of the sides of the hexagonal plates, as shown in the enlarged figure (14) of one of the plates. The pores are small in this species, but their position on the sutures is readily observable, and cannot be mistaken.

Parisocrinus subramosus M. & G. Pl. XVI, figs. 1, 2, 3, 4.

This is a rare species from the Keokuk limestone at Crawfordsville and Indian Creek, Indiana, of which I possess three specimens from the latter locality, showing the pores in the ventral sac. Figure 1 represents a nearly entire specimen,

somewhat enlarged, in which the sac is exposed. The sac, especially in the lower part, is covered by a very sharp and prominent stellate ornamentation, composed of conspicuous ridges running from the middle of each plate to the angles, and there connecting with corresponding ridges on adjacent plates. This stellate surface arrangement, although most pronounced in the lower part, is quite plain up to the distal end. Throughout the exposed parts of the sac there are distinct and well formed pores, which are without exception located on the radial lines, at the middle of the sides of the hexagonal plates. They are on the sutures in the depressed portion of the plates, between the ridges. The arrangement of the pores and ridges is more plainly shown by figure 2, which gives an enlarged view—4 diameters—of one of the plates with its connections.

In order to determine the question whether these pores are mere surface ornamentation, or actual openings through the test, I have taken a portion of the ventral sac of another specimen, and ground off all projections upon the surface until it is perfectly smooth, and have also ground down the fractured end so as to obtain a transverse section. The results of these operations are shown by figures 3 and 4. Fig. 3 is the polished outer surface, disclosing the sutures between the plates, and the pores on the sutures at the middle of the sides. The plates are rather irregularly hexagonal, and though perfectly smoothed off, preserve to some extent their stellate outline. The pores are not of uniform size or shape, but their position is the same throughout, viz., at the middle of the sides. Fig. 4 is the cross-section at the upper end of fig. 3; the inner cavity of the flattened tubular sac is plainly shown by the dark substance with which it has been filled by infiltration. The section cuts two of the pores, one large and one small one, which are seen at the upper edge of fig. 3. These are shown in the cross-section to pass from the exterior directly through the plates and connect with the inner cavity, being filled by the same kind of darker infiltrating substance. The connection of these pores in the two views is shown by the dotted lines. In preparing this specimen I ground off the cross-section for a considerable distance, and in doing so encountered several pores, and in every case I

found them to penetrate the sac to a connection with the inner cavity, just as those shown by these figures. We should of course not expect to find a greater number of pores exposed by one cross-section, as they are not arranged in transverse lines. The pores in this species are not found on every side of every plate in the sac, but they are very numerous, and whenever they occur, it is in the invariable position above described.

Scaphiocrinus arboreus Worthen. Pl. XVI, figs. 18, 19, 20, 21, 22, 23.

Although the foregoing examples, especially the last one, would seem to be sufficient for the present purpose, I will, for still further assurance, offer a study upon one more species, of which I have material in such preservation and abundance as to afford the best means of all for demonstrating the nature of the structures in question. This is *Scaphiocrinus arboreus,* from the St. Louis limestone at Huntsville, Alabama, where it has been found in considerable numbers. It is a small species, of the type of *Scaph. unicus* from the older Keokuk limestone, and is apparently its direct descendant. Its sac has the same peculiar crest of large plates, which are here only tumid, or very slightly spiniferous, and the anal opening is about half way down on the anterior side. The main portion of the sac below the crest, instead of having the profuse stellate ornamentation of *S. unicus*, is in most of the specimens nearly smooth. In some few places the stellate ridges are obscurely indicated. Out of a considerable number of specimens disclosing portions of the ventral sac, I have about twenty-five in which the pores are plainly visible in various parts of the sac. The sacs are in almost all positions, and in some cases the plates are well separated, so that the edges can be seen. The substance of the fossils is an exceedingly fine grained carbonate of lime, somewhat silicified, and of a rather light gray color. The matrix is an equally fine grained silicious limestone, of darker color than the fossils. All the cavities, being filled up by the infiltration of this fine material, show darker than the test. Wherever pores exist they are perfectly visible, and in some places the infiltrating material has been dissolved out again, leaving the

pores as empty holes. In most places the surface of the sac is perfectly smooth and even, so that the location of the pores is not complicated or obscured by any surface ornamentation or irregularities. In all of these specimens the pores are well defined, and are located invariably on the sutures at the middle of the sides of the hexagonal plates, and never at the angles. I have figured several specimens, to show the structure in as much variety as my space would admit. Figures 18 and 19 give anterior and posterior views of a nearly entire specimen, slightly enlarged, with the arms broken off so as to expose the upper, curled portion of the ventral sac, which is here profusely perforated, on both sides, with large pores. Fig. 20 gives a posterior view of the exposed part of the same sac, enlarged three diameters, so that the sutures of the plates, and the position of the pores in relation to them, may be more clearly seen. Fig. 21 shows the ventral sac of another specimen in a different aspect, enlarged two diameters. Fig. 22 is a view of another specimen, enlarged two diameters, showing the general form of the sac, and the pores on the posterior side, where some of the larger plates are stellate. In all the foregoing figures, except the last in part, the surface of the specimens is in its natural condition, smooth and devoid of ornament. In fig. 23, however, I show the sac of another specimen which I have ground off and polished so that all trace of the original surface has been removed, and the sutures and pores appear at a level which was perhaps half way between the outer and inner surfaces of the plates. Here also the sac is seen to be thickly perforated by pores which are always at the middle of the sides of the plates, and never at the angles.

In view of the foregoing evidence, I do not think any one will longer dispute the existence of pores which penetrate the ventral sac in certain Fistulata. In fairness, however, both to Mr. Bather and to Wachsmuth and Springer, I wish to be understood as limiting the statement to that contained in our Monograph already quoted, viz., that "among the Poteriocrinidæ, in many cases, the pores pass through the test." (p. 114, note); and the passage in the text on the same page that in the Fistulata "the sac . . . is generally composed of longitudinal rows of hexagonal plates, which are often pitted

at their sides, or perforated by pores." How general the rule is I am unable to say, as in the majority of fossil forms the preservation is insufficient to show the true structure. Upon the theory that these pores were subservient to respiration, it would be reasonable to expect them to exist generally in those Fistulata which were not provided with a madreporite as in *Cyathocrinus*. But I am as yet unable to prove that such is the case. There are certain Poteriocrinidæ in the Burlington limestone, *e.g. P. doris*, with a very large and often well preserved ventral sac, in which I have not been able to identify any pores in the parts of the sac which are exposed. There are depressions, very similar to those figured by Bather in *Botryocrinus* and *Thenarocrinus*, which run to the angles of the plates, in the bottom of which the sutures can be seen to meet. These are totally different structures from those illustrated in this paper, and I cannot assert that any pores exist in them. In these forms the sac was of enormous size, and we scarcely ever have it preserved to the distal end. It may be that the pores existed at some other part than that observed, but this is only conjecture, without present proof. To this extent, therefore, the statement made by Wachsmuth and Springer on this point in the Revision of the Palæocrinidæ was somewhat more general than the proved facts bear out, but as limited in the Monograph it is strictly correct.

EXPLANATION OF PLATE XVI.

Parisocrinus subramosus M & G.

Fig. 1. Specimen showing part of perforated ventral sac........ $\frac{1\frac{1}{2}}{1}$

Fig. 2. Single plate of same, showing the large, round pores, penetrating the plates on the suture lines at the middle of the sides, in the depressions between the ridges......... $\frac{4}{1}$

Fig. 3. Part of ventral sac of another specimen near the distal end, from which all surface ornamentation has been removed by grinding, exposing the sutures and the pores at the sides of the plates.................................. $\frac{8}{1}$

Fig. 4. Transverse section at the upper end of same specimen, showing pores passing through the plates to the interior of the sac.... .... $\frac{3}{1}$

Decadocrinus tumidulus M & G.

Fig. 5. Specimen showing part of ventral sac perforated with pores.. $\frac{1\frac{1}{2}}{1}$

Fig. 6. One plate and parts of connecting plates from the same specimen, showing large elliptic pores in median plate, and smaller round ones in those on either side. Here the pores lie in the ridges along the radial lines............ $\frac{4}{1}$

Scaphiocrinus unicus Hall.

Fig. 7. Plates of the ventral sac, two of them on edge. The pores lie in the ridges at the sides of the plates, not at the angles; and are represented by grooves passing over the edges of the plates.................................... $\frac{4}{1}$

Scytalocrinus hoveyi Worthen.

Fig. 8. Plates of ventral sac in similar position to those of fig. 7. Pores represented by more numerous slits or grooves passing across the edges of the upturned plates............ $\frac{4}{1}$

Scytalocrinus validus Worthen.

Fig. 9. Specimen with ventral sac nearly complete, showing pores on the suture lines at the middle of the sides of the plates; surface smooth.................................... $\frac{4}{1}$

Fig. 10. One plate of the same specimen.......................... $\frac{4}{1}$

Aulocrinus agassizi W & Sp.

Fig. 11. Specimen showing nearly entire ventral sac, with anal tube broken. Pores at the middle of the sides of the plates.. $\frac{1}{1}$

Fig. 12. Single plate of the same specimen....................... $\frac{4}{1}$

Scytalocrinus van hornei Worthen.

Fig. 13. Specimen preserving ventral sac perforated by small pores at middle of plates. Surface perfectly smooth...... $\frac{1}{1}$

Fig. 14. Single plate of same specimen............................ $\frac{4}{1}$

Scaphiocrinus missouriensis Shumard.

Fig. 15. One plate of ventral sac, with connections, showing the slits or fissures passing from plate to plate................ $\frac{4}{1}$

Scaphiocrinus swallovi M & W.

Fig. 16. One plate of ventral sac, with parts of contiguous plates, showing the large elongate pores in depressions at middle of sides... $\frac{4}{1}$

Decadocrinus grandis W. & Spr.

Fig. 17. Plates of ventral sac with terminal spine, showing the pores at the sides of the plates, and also between the plates and the tèrminal spine........................... $\frac{4}{1}$

Scaphiocrinus arboreus Worthen.

Fig. 18. Entire specimen, showing upper part of perforated ventral sac, anterior view.................................... $\frac{1\frac{1}{2}}{1}$

Fig. 19. Same specimen, posterior view.............................. $\frac{1\frac{1}{2}}{1}$

Fig. 20. Exposed part of the ventral sac shown in fig. 19, with the pores on the sutures at the middle of the sides of the plates... $\frac{3}{1}$

Fig. 21. The upper part of ventral sac of another specimen......... $\frac{2}{1}$

Fig. 22. Posterior view of another specimen, showing full length of tube, with pores on the suture lines at the middle of the sides of plates.. $\frac{2}{1}$

Fig. 23. Part of the ventral sac of another specimen ground off to half the depth of the plates, showing perforation of the sac by pores at the middle of the sides of the plates.... $\frac{3}{1}$

MINERALOGICAL AND PETROGRAPHIC STUDY OF THE GABBROID ROCKS OF MINNESOTA, AND MORE PARTICULARLY, OF THE PLAGIOCLASYTES.*

(Plates VIII to XIX.)

By ALEXANDER N. WINCHELL, Butte, Mont.

CONTENTS.

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*The facts presented in this series of papers are essentially the same as those which appeared in the form of a thesis, presented to the Faculty of Sciences of Paris to obtain the title of Doctor of the University of Paris, and entitled: Etude minéralogique et petrographique des roches gabbroïques de l'Etat de Minnesota, Etats Unis, et plus specialement des anorthosites. Paris 1900.

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INTRODUCTION.

The great continental nucleus, which Dana has called the "North American protaxis," extends, as is well known, from the eastern limits of Labrador to the head waters of the Mississippi river and from New York state to the Arctic islands of

the Polar sea. It is roughly triangular in outline with its base toward the north. The surface of this whole country has well marked characteristics; it is rarely or never mountainous, and at the same time it is exceptional to find in it a level plain of any extent; it is generally wooded except in the far north where the climate is too severe. The contours are so irregular that it is pre-eminently a country of lakes* and hills, which give it a rugged charm of its own.

Perhaps the most marked irregularity in the outline of this huge triangle is caused by an extension from the western side toward the southwest. This projection occupies the northeastern part of the state of Minnesota, and the adjacent portions of Canada, lying to the north and west of lake Superior. Within this small area are found the watersheds separating the head waters of three great river systems: to the north the Red river and Rainy river whose waters uniting in lake Winnipeg are carried to Hudson bay through the Nelson; to the east the St. Lawrence system draining the five great lakes; to the south the Mississippi, finally reaching the waters of the gulf of Mexico. The head waters of these river systems, instead of being in a high and mountainous district, occupy an area remarkably low, and not a single mountain exists in the district. The highest altitude anywhere in Minnesota is less than twenty-three hundred feet above sea-level, while the average elevation of the watersheds is undoubtedly less than two thousand feet.

The series of rock types which form the subject of this paper all come from the triangular area of Minnesota lying to the north of lake Superior, and to the east of the meridian of Duluth. This area forms a large part of one side of the great geosynclinal which is occupied by lake Superior. Nearly every important rock type and formation existing on the north side of the lake are duplicated on the south side in Wisconsin and Michigan, and, in a general way, the succession of geological horizons from southeast to northwest found in Minnesota is repeated on the south side, but in reverse order. From lake Superior, on the northern side, the land rises rapid-

*The borders of great Archean protaxis coincide very closely with the axes of several of the great American lakes, e. g., Great Slave, Great Bear, Winnipeg, and Superior; while the whole area is, in general, included quite accurately between the St. Lawrence, the Rainy, and the Mackenzie rivers.

ly to the summit of the Mesabi range, which, at a distance of about fifteen miles from the lake, reaches an altitude of a thousand to fifteen hundred feet above the great inland water. Once the summit of the Mesabi hills is reached, the surface, while very uneven, and even rising to the lower Vermilion range, descends, in general, very slowly towards the northwest. The backbone of the Mesabi range is composed of gabbro—the normal olivine gabbro, rather rich in alkaline-earth elements, which is the central typical rock of our study. Its general location and wide extent are shown on the accompanying map.

But with this dominant type occur variations and modifications. Thus in many places along the northern edge of the gabbro area, the rock has been profoundly affected by metamorphism, and it is from this region that the cordierite noryte, quartz gabbro, and silicoferrolyte are derived. Plagioclasytes (anorthosytes*) and diabases occur occasionally in the gabbro area itself. The troctolyte to be studied came from an area near Duluth, but several other areas of this rock are known further north, surrounded by gabbro. The orthoclase gabbro also came from Duluth, where it forms the country rock; it is also known at various other localities in Minnesota and Wisconsin.

The general shape of the area occupied by these rocks is rudely that of a crescent, with one extremity near Greenwood lake pointing eastward, and the other near Duluth pointing southward. The extreme length of the crescent is about one hundred and twenty-five miles, and the maximum breadth is nearly twenty-five miles. The total area of this crescent of gabbro rocks amounts to about two thousand square miles. But outside of this crescent occur two smaller areas of diabasic rocks, and various outlying masses of gabbros and plagioclasytes. The first of these areas extends west and southwest from Pigeon point for about forty-five miles, covering a surface of about one hundred and fifty square miles. From the eastern extremity of this area was obtained the type of olivine

*The term anorthosyte has produced so much confusion that it can well be replaced by the name plagioclasyte, proposed by the French Commission of rock nomenclature. The latter will be used throughout this article.

diabase for our study. The second area borders lake Superior from a point intermediate between Duluth and Two Harbors to beyond Poplar river; the length of this shore line exceeds seventy-five miles, while the surface occupied approximates six hundred square miles. This region is composed chiefly of diabase types, which have recently been shown to belong to two different epochs. But it also includes several small masses of gabbro and plagioclasyte, especially at Encampment island, Beaver bay, and Carlton peak. The last named attains an altitude of about six hundred feet above the lake; the type of plagioclasyte studied came from the summit of this peak, where large masses of nearly pure feldspar are found.

The geological literature of this region has become very voluminous within the last twenty years, and the limits of this paper prohibit any extensive bibliographies, which would, moreover, be largely superfluous since several able reviews of the literature already exist. Van Hise* has published an exhaustive bibliography of early Cambrian and Archean American geology, with extended summaries; Bayley† has presented a very useful review of the literature of the petrography of gabbro rocks, especially as found in the lake Superior region; Elftman‡ has brought the bibliography of Minnesota gabbros nearly up to date, and Adams§ has given a special bibliography of the anorthosytes.

The present study is from the petrographic and mineralogical points of view. Among the more important contributors to the petrographic knowledge of the gabbros of Minnesota may be mentioned: Streng (1877), Irving (1883), Wadsworth (1887), N. H. Winchell (1891 and later), Grant (1893), and Bayley, (1893 and later). The mineralogy of the series has been slighted until very recently, when N. H. Winchell¶ has made a detailed study of various minerals.

*C. R. Van Hise: Correlation papers: Archean and Algonkian: U. S. G. S. Bull. 86, 1892. See also: Current Precambrian literature: Jour. Geol. 1893. I.; 1895, III; 1896, IV.

†W. S. Bayley: The basic massive rocks of the Lake Superior region: Jour. Geol. 1893, I; 1894, II; 1895, III.

‡A. H. Elftman: The geology of the Keweenawan area in northeastern Minnesota: Amer. Geol. 1898, XXI.

§F. D. Adams: Uber das Norian oder Ober-Laurentian von Canada: N. Jahr. f. Min., etc.: 1893. VIII.

¶N. H. Winchell: Contributions to the mineralogy of Minnesota: Amer. Geol. 1899. XXIII. See also: Final Report: Geol. Nat. Hist. Surv. Minn., 1900, V.

The most recent study of this part of Minnesota has appeared within the last two years in the form of volumes IV and V of the final report of the geological and natural history survey of Minnesota by the state geologist, Prof. N. H. Winchell. The views therein presented are those reached after a long and detailed as well as comprehensive study, not only in the field but also in the laboratory, of the whole rock series found in northeast Minnesota. These conclusions will be accepted here. To commend, or to criticize them are equally beyond the purposes of this paper.

The conclusions of the state geologist of Minnesota differ radically in one important respect from those of all previous writers. The gabbros have been considered heretofore to be of deep-seated eruptive origin. On the other hand Prof. N. H. Winchell presents evidence to show that they have been derived from the fusion of the great terrane which has been called "greenstone" in the Archean, and that they vary in structure and composition because the greenstones originally varied. The gabbro still retains in some places the original bedding of the greenstones, which are themselves generally very basic rocks, but become acid by the acquirement of clastics or detritals.

According to Prof. N. H. Winchell the evidence that the gabbro has been formed at the expense of the greenstones is of two categories:—

1. All the minerals of the gabbro recur in the noryte (transition type between the gabbro and the greenstones) or are represented by their homologues. But in the noryte they present a very interesting texture and frequently enclose quartz in poikilitic fashion. Cordierite, fayalite, diallage, augite, hypersthene and labradorite are abundant; sometimes also enstatite, magnetite, biotite and quartz, more rarely anthophyllite or cummingtonite. All these minerals have been formed in peculiar physical conditions which have caused them to take the globular form, so frequent in secondary minerals produced under the influences of metamorphism.

2. In certain localities the gabbro passes by insensible degrees to the muscovadyte, or noryte, and the latter to greenstone. These passages occur both in normal masses and in cases where the rock is conglomeratic. In the latter case the

rock throughout the series of changes encloses conglomeratic masses of varied nature, which are more or less intact in the muscovadyte and less distinct in the gabbro.

The muscovadyte is always the intermediate phase between the greenstones and the gabbro. Sometimes one and sometimes the other predominates. Nevertheless the gabbro is sometimes clearly later than the muscovadyte.

These three rocks are therefore necessarily allied genetically, and since the greenstone is sometimes clearly a clastic rock it is the gabbro which has been produced from the greenstone and not the reverse; if the latter had occurred abrupt passages would occur between the gabbros and the greenstones and the former would be found in a detrital state.

Prof. N. H. Winchell applies these conclusions to all the massive rocks of the region whose present mineralogical composition is accordingly a function of the original mineralogical composition of the rocks at whose expense they have been formed by the process above outlined. The most acid of the latter gave rise to granites, the intermediate to quartz gabbro, etc. The transformation of the basic greenstones to gabbros is therefore only a particular case of a phenomenon much more general.

The greenstones are primarily of igneous origin, being the oldest known rocks of the earth's crust. The great refusion epoch which produced the gabbro dates from a period after or just at the close of the Animikie, in Minnesota. Such a refusion naturally produced a molten mass which acted under stress like any ordinary eruptive rock, and indeed the resultant magma not only produced on cooling in place the various gabbros, but also protruded itself as an intrusive between the pre-existing rocks in the form of numerous laccolitic sills, and dikes in all positions. It further produced lava flow, when it reached the surface, and even seems to have produced volcanic ash and sinter.

Over the area of the present gabbro mass the overlying rocks have been removed by the varied processes of erosion. and by glaciation. If any remnants of the superjacent rocks still exist, they are covered by glacial drift, or, at least, have not yet been discovered. According to the taxonomy of the Minnesota survey as expressed in final form, the oldest rocks

of the state (and of the world) are the greenstones, which are both massive, igneous, and clastic. With them are associated schists, gneisses, granites, quartz porphyries, and jaspilytes (iron ore rock) in the Lower Keewatin. The gneisses and granites placed in the Laurentian by the United States Geological Survey are considered by the Minnesota Survey to be of later date than the greenstones, and to be derived from clastics by metamorphism. An unconformity followed by the Ogishkie conglomerate separates the Lower from the Upper Keewatin, which consists of a series of argillytes, graywackes, etc. These two divisions of the Keewatin together constitute the Archean in Minnesota, and are followed by a great unconformity. The Keewatin formations are invariably nearly vertical in position; the succeeding series dips at a comparatively low angle, or may even be horizontal. The oldest terrane of the Paleozoic is called theAnimikie in Minnesota; it is composed of quartzytes, slates, etc., and contains the richest iron mines in the world. The Keweenawan, in its widest sense, is composed of two members: the Cabotian, and the Manitou. The lower division (Cabotian) rests upon the Animikie, perhaps unconformably. It is composed in Minnesota exclusively of igneous rocks, and it is a name intended only for such rocks; but it represents a time interval elsewhere occupied by sedimentaries. The Keweenawan, as a time interval, should be limited to the epoch immediately following the Puckwunge conglomerate, which marks the unconformity existing between the Cabotian and the Manitou. The latter is a term also intended to designate igneous rocks, but even in Minnesota sedimentaries begin to appear from the first dawn of the epoch, and towards its close sandstones predominate. These three: the Animikie, Cabotian and Manitou, together constitute the Taconic, which is equivalent to the Middle and Lower Cambrian. The upper sandstones of the Manitou pass insensibly into the sandstones of the Upper Cambrian, whose later members show characteristic fossils.

If this classification be correlated with that adopted by the United States Geological Survey, fundamental differences will be found, especially in regard to the series of gabbros which are to be studied in this article. It must be noted in the first place that correlations are always difficult and dangerous, and

that they can only represent in a very general way the various, and often complicated equivalencies. Within these limitations, however, an approximate correlation seems possible, and is expressed in the following tabulated form.

The feature of the classification of the United States Geological Survey which is most distinctive, fundamental, and conspicuous is the introduction of the Algonkian (Precambrian) system, which is not recognized by the Minnesota survey. The Archean in Minnesota is thus limited to a portion of the Lower Keewatin, composed of the rocks that are so old as to show no clastic characters, that is, the main body of the greenstones, with the oldest schists and gneisses. The Archean is divided into two groups wholly on lithological grounds. The Laurentian includes the granites and granitoid gneisses; the Mareniscan embraces the fine grained mica schists, hornblende schists, hornblende gneisses, and even some feldspathic schists. The distinction is clearly somewhat arbitrary, and the two divisions frequently pass one into the other by imperceptible transitions. But in Minnesota they are said to be separated by an eruptive unconformity. The Lower Huronian rests unconformably upon the Archean, and is separated by another unconformity from the upper Huronian. The first unconformity is not recognized by the Minnesota survey; the second separates the Lower from the Upper Keewatin. The Lower Huronian comprises the jaspilytes, quartz porphyries, and the clastic portions of the greenstones, which latter are considered to be quite rare and unimportant. The Upper Huronian includes the argillytes, certain quartzytes, graywackes, etc., and its basal member is the Ogishkie conglomerate. The great unconformity between the Upper Keewatin and the Animikie is not recognized by the United States Geological Survey in the Upper Huronian; or, rather, perhaps, it is placed at a higher level between the Huronian and Keeweenawan. The Lower Keeweenawan, though, necessarily tabulated as the equivalent of the Cabotian, is not so in fact, since it includes various sandstones and conglomerates not admitted in the latter. The unconformity above the Cabotian is not recognized in the Keeweenawan by the United States survey, though it is stated that an unconformity probably exists. But it is at the upper limit of the Keeweenawan that a

	Nomenclature of the Geological and Natural History Survey of Minnesota.	Rock series in Minnesota.	Nomenclature of the United States Geological Survey.	
Paleozoic.	Upper Cambrian	Hinckley sandstone St. Croix sandstone Western, or Lake Superior sandstone	Upper Cambrian	Paleozoic.
			← Unconformity	
		Sandstone (not found in Minnesota)	Upper Keweenawan	Algonkian.
	Taconic. (=Middle and Lower Cambrian). Keweenawan. Manitou	Sandstones, shales, etc., } interbedded. Diabases, lavas, etc. } Puckwunge conglomerate		
	Taconic. Keweenawan. Unconformity →			
	Taconic. Keweenawan. Cabotian	Gabbros, plagioclasytes Diabases Red granites, etc.	Lower Keweenawan	
	Taconic. Unconformity →		← Unconformity	
	Taconic. Animikie	Argillytes Quartzyte (Mesabi iron ores)	Probably Upper Huronian	
	Great unconformity →			
Archean.	Upper Keewatin	Argillytes, graywackes. Ogishkie conglomerate	Upper Huronian	
	Unconformity →		← Unconformity	
	Lower Keewatin	Jaspilytes, etc. Quartz porphyry Clastic greenstones	Lower Huronian	
			← Unconformity	
		Massive greenstones Various schists	Mareniscan	Archean.
			← "Eruptive unconformity"	
		Gneisses Granites	Laurentian	

difference of the most far-reaching importance exists. The national survey here recognizes a great unconformity which is taken to represent an erosion interval during the whole of Middle and Lower Cambrian time; the corresponding formations consequently are considered to be absent in this region, as well as in many other American localities where the Keeweenawan is typically developed. Thus the Algonkian is made to include not only a large part of the Archean of the state survey, but also comprises a vast series of rocks (Animikie, Cabotian, and Manitou) which are ranged by the latter in the Paleozoic. On the other hand no unconformity at all is admitted directly above the Manitou by the state survey, and the Keeweenawan and Animikie are held to represent the Middle and Lower Cambrian, though the parallelisms can not be drawn more closely. When the fossiliferous members of the Upper Cambrian are reached the differences no longer exist. Below these beds only three or four undoubted fossils have been found (one has been announced as early as the Animikie) and these have not proved sufficiently characteristic to settle any of the points in question. There can be no doubt that life existed during the Keeweenawan and even during the Huronian, not only from theoretical considerations, and from the occasional presence of abundant carbon, and hydrocarbons, but also from the presence of very rare fossils. But until a distinctive fauna is discovered and studied no reliance can be placed on the paleontological evidence.

According to the latest utterances, therefore the central type rock to be studied is the result of a great refusion of Archean greenstones which took place at the close of Animikie time. It belongs to the Cabotian series of igneous rocks, since the refusion inevitably produced a magma similar in all its effects to an ordinary eruptive: This magma consolidating at considerable depth produced gabbros of varying composition; consolidating in intruded laccolites and dikes it produced diabases; and finally as a surface rock it produced amygdaloids, lavas and even probably volcanic ash. When the greenstones were more acid from any cause the resultant rock may be an augite syenyte or even a granite.

The following series of rock types were kindly furnished

the writer for study by the director of the Geological and Natural History Survey of Minnesota:

1. Olivine gabbro (1136), collected by M. E. Wadsworth, from a point one-half a mile west of the line between sec. 31, 62-11, and sec. 6, 61-11, in T. 61, near Birch lake. Shows a slight tendency toward the ophitic texture.

2. Diabase poor in olivine (954), collected by N. H. Winchell from the east side of Birch lake on N. W. ¼ sec. 17, 61-11. Called "gabbro" by N. H. Winchell, on account of a distinct tendency toward the granular texture.

3. Olivine diabase (1843), collected by N. H. Winchell from the extremity of Pigeon point. Sometimes called "gabbro"* to distinguish it from the fine-grained diabases which abound in the same locality.

4. Plagioclasyte (336E), collected by A. H. Elftman from the summit of Carlton peak.

5. Troctolyte (514), collected by N. H. Winchell from near Duluth. Also called forellenstein.

6. Silicoferrolyte (960), collected by N. H. Winchell from a low ridge of fifteen rods from the shore of Birch lake, S. W. ¼, sec. 24, 64—12. Called "olivinitic iron ore," in the reports of the Geological and Natural History Survey of Minnesota.

7. Quartz gabbro (854G and 854 (A) G), collected by U. S. Grant, from S. E. ¼, S. W. ¼ sec. 12, 64—6, southwest shore of small lake near Little Saganaga lake. 854 (A) G is the porphyritic variety.

8. Orthoclase gabbro (1797), collected by N. H. Winchell, from Duluth.

9. Hornblende gabbro (1797), collected by N. H. Winchell, from Duluth.

10. Cordierite noryte (983), collected by N. H. Winchell, from sec. 15, 63—9, not far from Snowbank lake. One of the "muscovadytes" of the Minnesota Survey.

It is the purpose of the present article to study these types from the petrographic, mineralogical, and chemical points of view. Their geological relationships, their taxonomic position and all questions of general geology will form no part of the study. In a general way these questions will be considered as settled according to the principles and conclusions of the final report of the Minnesota Survey. The field relations and general geological relations will be given for each type, so far as they have been established by other studies, in order that they

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*See Bayley: The eruptive and sedimentary rocks of Pigeon point, Minnesota: Bull. 109. U. S. Geol. Survey, 1893; et al.

may throw all the light possible upon the petrographic questions which may arise.

The following rocks will be studied:

Olivine gabbro (chapter I).
Normal diabase (chapter II).
Olivine diabase (chapter III).
Plagioclasyte (chapter IV).
Troctolyte (chapter V).
Orthoclase gabbro, hornblende gabbro (chapter VI).
Cordierite noryte (chapter VII).
Quartz gabbro (chapter VIII).
Silicoferrolyte (chapter IX).
In conclusion a final chapter will be devoted to a résumé and comparative study of the series.

CHAPTER I. Olivine Gabbro.

Although we are studying an area composed largely of gabbro of nearly every variety, the normal deep seated gabbro of the petrographers is decidedly rare; indeed, the writer has not been able to obtain a typical sample. It occurs*, but only locally, and as a variation from the prevalent plagioclasyte, where the latter rock is unusually rich in augite. It would then consist of a holocrystalline granitoid aggregate essentially made up of plagioclase and pyroxene in approximately equal amounts, with more or less magnetite and a few small crystals of apatite. But if strictly normal gabbro is rare, the same is not true of normal olivine gabbro, which is the dominant rock of the main crescent-shaped area which we are studying. Its geological relations have already been indicated. It is a rock of very uniform structure† and composition. Apart from a rude bedding, due to localization of the pyroxene, or olivine, or both in certain bands and their rarity in others, the structure is always typically granitoid. The grain varies from medium to coarse, but the latter is more frequently seen. The rock is always massive and presents in contour a very irregular outline of large, low rounded hills, spreading over immense tracts of country. The banding or gneissic structure is only evident after weathering, the olivine especially altering and dis-

*See R. D. Irving: Copper-bearing rocks of lake Superior: Geol. Wis., III, p. 176.

†Cf. W. S. Bayley: The basic massive rocks of the Lake Superior region: Jour. Geol., 1893, I, p. 698.

integrating easily. This bedded structure is probably not due to pressure or to any process of differentiation but is ascribed by Winchell * to the original sedimentary condition of the formation.

The color of the rock is in general a dark grayish green varying to dark green, as the ferromagnesian minerals become more abundant. Fresh fractures show the bright lustrous cleavages of the feldspar, as well as the much darker cleavages of the pyroxene. The common albite twinning striations are visible nearly always on the feldspar, which is often more abundant than the pyroxene. The plagioclase anhedra are usually larger and perfectly fresh and glassy. The augite is jet black in mass, but thin splinters are greenish-black. It usually crystallizes without any definite form, but is occasionally triangular or wedge-shaped. Magnetite is easily detected also by its bright metallic reflections of blue black color; it is often abundant. Biotite is often conspicuous by reason of the perfection of its cleavage, giving the brightest reflections of a brown to black color, from faces absolutely uniform; but microscopic study shows that the biotite is usually, if not always, a secondary reaction product formed from the feldspar and the ferriferous minerals. Olivine can be detected by the olive-green to yellow color of the rather small crystal grains. As elsewhere noticed it is only rarely entirely lacking, though it is usually not abundant. Pyrite sometimes occurs very sparingly. When decomposed the feldspar becomes white and opaque, apparently an aggregate of minute grains. At the same time the olivine loses the lustre and transparency of its perfect state, and changes to an earthy mass of minerals belonging to the group of antigorite; they are usually dark green. The augite may also alter, first to biotite and then to chlorite.

The texture of the normal gabbro is always granitic, usually coarse to medium grained. (See plate VIII, figure 1.) It is only when it solidified near the surface, usually in the form of intrusive sheets, which occur along the northern edge of the gabbro mass, and more commonly in the northeastern part, west from Pigeon point, that the rock passes into a dia-

*N. H. Winchell: Final Report: Geol. Nat. Hist. Surv. Minn., Vol. IV and V, 1899 and 1900.

base by assuming the ophitic structure. Magnetite, olivine, augite, and labradorite are always present as primary constituents, and apatite can usually be found also, ordinarily in extremely small amount. The apatite usually crystallized very early, but its relation to the magnetite has never been observed; it is often enclosed in good crystal form within the augite, less commonly it is surrounded by labradorite, or some one of the other minerals. Since the augite alters sometimes to biotite, apatite is often found enclosed in the latter mineral. The magnetite usually shows no good crystal outlines, but in the few cases where they occur the iron oxide is clearly older than the other minerals. The augite in particular has been observed molding itself sharply around clear cut contours of magnetite. (See plate XVII, figure 1.) The iron oxide is oftenest in irregular grains and masses, frequently between plagioclase anhedra, but also occurs included within them. It is practically never absent, but is seldom abundant. There is very little doubt that the fine acicular inclusions in the feldspar, as well as dust-like particles which are usually most abundant in the plagioclase, but can frequently be found also throughout the rock, are all to be referred to magnetite, usually titaniferous. Olivine is very rarely absent, and may be quite abundant. Its period of crystallization was probably ended at or before the time when the pyroxene began to solidify, and it served as a sort of support upon or against which the augite crystallized. Thus the olivine is often entirely surrounded by a rim of pyroxene which may finally grow out in some direction and form a distinct crystal (not a mere rim) though it is usually oriented like that around the olivine. That these rims are not "reaction rims" is well shown by their development, thus, away from the olivine, as pointed out by Bayley*. Occasionally the olivine is apparently later than the augite. (See Plate XVII., figure 1.)

The pyroxene is in general automorphic toward the feldspar in which it is frequently enclosed. This rule is subject, however, to distinct exceptions, where the augite occurs in irregular patches or triangular areas between the labradorite grains and is clearly younger than the latter. Such exceptions

*W. S. Bayley: The basic massive rocks of the Lake Superior Region: Jour. Geol. 1893. I, p. 706.

show that while the crystallization of the pyroxene began some time before that of the plagioclase, it was still uncompleted when the latter mineral had solidified in large measure.

The plagioclase, while in general the last of the original minerals to solidify, began to crystallize some time before the crystallization of the pyroxene had reached its conclusion. Thus it is that these two minerals not unfrequently seem to show a reversal of the normal order of crystallization. Nevertheless true ophitic texture is never present, even in limited areas, in the normal gabbro. Its appearance marks the passage to diabase; all stages of this passage can be found, but yet it is nearly always very easy to distinguish the gabbro from the diabase. Indeed it is asserted by Bayley* that the granitic variety can never be traced into the ophitic variety in the field, and that their contact whenever found is very sharp. Lawson† on the other hand, asserts that insensible gradations from the finest ophitic textures to the coarse gabbro texture often occur in the thickest intrusive sheets.

PRIMARY MINERALS. The *labradorite*‡ of the normal gabbro shows the characteristic twinning, nearly always, according to the albite, pericline and Carlsbad laws. The color is usually rather dark on account of the numerous inclusions of black magnetite needles. The extinction angle in sections perpendicular to n_g ($=\mathfrak{c}$) is $33\frac{1}{2}°$ to $34°$; in the same sections the angle between the albite and pericline twinning is $65°$, and that between the albite twinning and the trace of the plane containing the magnetite needles is $16°$. The extinctions in sections perpendicular to n_p ($=\mathfrak{a}$) is $58°$ to $58\frac{1}{2}°$, while the angle between the albite and pericline twinning in the same sections is about $77°$ or $78°$. Such sections cut the magnetite needles nearly at right angles, and they appear therefore to be mere particles without elongation. The plane in which they seem to lie makes an angle of $34°$ with the albite twinning. The acute bisectrix is n_g and $2V$ seems to be somewhat smaller than in the Carlton plagioclasyte, but no exact measurements

* Cf. Bayley loc. cit., p. 453. But Judd (Q. J. G. S., XLI, 1885, p. 361, & 1886, p. 40), and others hold the contrary view.

†A .C. Lawson: Laccolitic sills of the northwest coast of lake Superior: Geol. Nat. Hist. Surv. Minn. Bull. 8, 1893, p. 30.

‡A detailed study of the labradorite of the plagioclasyte will follow the description of that rock. See chapter IV.

have been made. The extinction angle in cleavage fragments parallel to $p(001)$ is 11° to 13°, and in pieces parallel to $g^1(010)$ it is about 26°. The maximum equal extinction measured on the albite twinning in the zone perpendicular to $g^1(010)$ varies from 35½° to about 40° in different specimens*.

All the analyses which have been made show that the mineral is a labradorite whose composition varies between that expressed by $Ab_3 An_4$ and $Ab_2 An_3$. The specific gravity varies from 2.700 to 2.712, but its average is only 2.704*. The analyses follow:

	I	II	III
SiO_2	53.45	52.61	52.50
TiO_2..............	trace	trace	trace
Al_2O_3	29.77	29.80	30.15
Fe_2O_3	.33	.57	.47
FeO	.15	.23	.15
MgO	.11	.20	.10
CaO	11.33	12.25	12.82
Na_2O	4.33	3.80	3.72
K_2O	.68	.53	.53
H_2O	.23	.29	.25
	100.38	100.28	100.69

I. Labradorite from gabbro from N. W. ¼, S. E. ¼, Sec. 23, T. 62, N. R. 10 W. Minn.; by W. F. Hillebrand; see Bull. 148, U. S. Geol. Survey, p. 112.

II. Labradorite from gabbro from Sec. 25, T. 64 N., R. 8 W. Minn. Ibidem.

III. Labradorite from gabbro from Duluth and Iron Range R. R., Minn. Ibidem.

The analysis under I represents a feldspar very near the composition expressed by $Ab_3 An_4$; the other two are of the composition $Ab_2 An_3$.

The pyroxenic element of the rock ordinarily belongs to the group of *diopside* being very poor in alumina; hypersthene only occurs as one approaches the contacts with other rocks. The pyroxene is occasionally distinctly automorphic; the faces $m(110)$ and $g^1(010)$ have been observed. Twinning parallel to $h^1(100)$ is not uncommon; the characteristic cleavages are usually well developed forming an angle of about 87°. Parting is often developed parallel to $h^1(100)$; more rarely

*Cf. Bayley: Jour. Geol. 1893, I, p. 700.

parallel to $g^1(010)$, and the mineral thus passes to diallage. In thin sections the mineral is very light colored and yet a distinct pleochroism can often be observed with:

Thickness .025 to .03 mm.	Thickness .1 ± mm
n_g = pale greenish	green
n_m = pale yellowish green	yellowish green
n_p = pink	brownish yellow

The refringence is higher than that of olivine as shown by the Becke method; the birefringence* is at least .022; the mineral is biaxial and positive with 2E very large. The dispersion about n_g is $\rho > v$.

The extinction in sections of the zone perpendicular to $h^1(100)$ bisects the angle of the cleavages; in sections of the zone parallel to the vertical axis the maximum extinction angle is found in sections parallel to the optic plane; this angle is higher than 30°.

The chemical composition of this mineral shows a notable amount of titanium; an analysis from a similar rock, but at some distance from northeastern Minnesota follows:†

	I
SiO_2	49.80
TiO_2	1.29
Al_2O_3	2.86
Fe_2O_3	2.48
FeO	10.82
MnO	.37
MgO	15.33
CaO	16.50
Na_2O	.51
K_2O	.12
H_2O	.33
	100.41

I. Diallage from gabbro from Ashland Co., Wis.; includes also traces of P_2O_5 and Li_2O (?): but no SrO nor BaO; by W. F. Hillebrand. See Bull. 148, U. S. Geol. Survey, 1897, p. 105.

*Throughout this article the value of the birefringence is estimated, unless otherwise stated, by means of the Tableau des Biréfringences of Michel Lévy and Lacroix (Minéraux des Roches, 1888), only such sections being used for this purpose as have a thickness not less than .025 mm. and not greater than .03 mm.

†No analysis of the Minnesota material has yet been made on account of the difficulty experienced in trying to obtain pure material.

Most of the iron is in the form of protoxide; the alkalies and water are in negligible quantity.

The *olivine* * of the normal gabbro is very rarely twinned; its cleavages parallel $g^1(010)$ and $p(001)$ can only be seen when the mineral has begun to alter. They then become very distinct, appearing as fine lines very straight and fairly continuous. The cleavage parallel to $g^1(010)$ is much better than the other; both are often accentuated by black, opaque inclusions probably of secondary magnetite. In mass the mineral is orange to olive-green; in thin section it is colorless. The crystal form of olivine is not uncommon, though the outline is usually more or less irregular, and the angles rounded.

The chemical composition of the olivine occurring not far from Birch lake shows it to be a hyalosiderite with the ratio Mg: Fe about 1.43:1. The olivine analyzed was almost wholly unaltered, and gave the following results:

	I
SiO_2	35.58
TiO_2	1.22
Al_2O_3	.92
F_2O_3	trace
FeO	33.91
MnO	.35
CoO	.20
NiO	?
MgO	26.86
CaO	.90
H_2O	.31
	100.25

I. Olivine from gabbro from S. E. ¼, S. E. ¼, Sec. 19, T. 63 N., R. 9 W., Minn., by W. F. Hillebrand. See Bayley: Jour. Geol., 1893, I, p. 703.

The high per cent of the titanium is interesting as showing that this might perhaps be termed titanolivine; it is at least an intermediate stage.

At the time of the consolidation of the gabbro all the superabundant iron oxide crystalized in the form of *magnetite*. In spite of its early crystallization, crystal outline is rare, except

*The olivine is frequently replaced in this rock by fayalite, according to N. H. Winchell.

in acicular form. It occurs in pegmatitic intergrowth with the pyroxene. (See plate VIII., figure 2.) By reflected light the octahedral parting can often be discerned. The mineral is strongly magnetic, but usually has no polarity. Its color is iron-black, with bright blue-black metallic lustre.

Though the mineral undoubtedly often contains titanium, it has never been seen to alter to leucoxene.

In direct contrast with the rarity of crystal form in magnetite is its frequency in *apatite*. Indeed it is rare to find apatite except in well formed, sharply limited crystals. These are hexagonal prisms, usually rather short, and terminated sometimes by the basal plane, and sometimes by pyramidal faces. Twinning has never been seen, and cleavage is rare and indistinct; it occurs, however, parallel to the base, and still more imperfectly in the large crystals, parallel to one or more of the prism faces.

Microchemical tests have shown the presence of phosphoric acid and calcium.

Apatite occurs generally in small crystals sparsely distributed; many sections contain none at all; it is so rare as to be practically without any effect upon the composition of the rock as a whole. It may be enclosed by any of the other minerals, though it most commonly occurs in the labradorite and augite.

Apatite sometimes occurs causing no halo in the surrounding mineral, whether that be labradorite, augite, brown or green hornblende, or biotite. In such cases the refringence of the apatite is always higher than n_g of the biotite. In other cases apatite always causes a halo when surrounded by biotite or hornblende. Finally it sometimes happens that in a single thin section apatite causes a halo in some biotite crystals and does not in others. A thin section of the Birch lake gabbro shows this peculiar condition. When the apatite causes no halo, apatite $n_g > n_g$ and n_m biotite.

In another case a transverse section with good outline causes a marked greenish brown halo in brown biotite (see plate XVII, figure 3). In this case:

Apatite $n_g > n_p$ biotite, difference considerable.
Apatite $n_g < n_m$ biotite, though nearly equal.

The refringence (n_g and n_m) of the biotite sometimes re-

mains inferior to that of the apatite (n_g or even n_p), though it is nearly always superior to the latter, when the halo is very marked. Thus other occurrences show

Apatite $n_p < n_g$ and n_m biotite.
. Apatite $n_g < n_g$ and n_m biotite.

The indices of apatite have been carefully measured several times; the results follow:

		Heusser	Schrauf	Lattermann	Zimányi
Apatite	n_g =	1.6460	1.6390	1.6388	1.637
	n_p =	1.6417	1.6345	1.6346	1.633

The indices of phlogopite have been determined by Michael Lévy and Lacroix* as follows:

$$\text{Phlogopite, of Templeton, Canada.}\begin{cases} n_g = 1.606 \\ n_m = 1.606 \\ n_p = 1.562 \end{cases}$$

It must be added that the indices of biotite are somewhat variable, as is shown by the variations in the value of the birefringence; the birefringence of the biotite in question here does not exceed .050.

Michael Lévy† has shown that the refringence generally increases in pleochroic halos, and estimated from the intensity of the white line between the halo and the surrounding mineral (Becke method) that this increase may exceed .01, notably in halos in cordierite about zircon.. But the same method applied to the present case indicates that the increase in the value of the refringence due to the halo is comparatively slight, so that the facts stated above can be accounted for only on the assumption, either that the apatite in question has a refringence abnormally low, or that the biotite has a refringence very unusually high. The fact that repeated measures of the indices of apatite have given values very concordant and the fact that the indices of biotite are known to vary render it probable that the second assumption is the correct one.

The birefringence in the halos above studied is increased probably about .007, at least .006, which is equivalent to an increase of at least 12%.

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*Michel Lévy and Lacroix; Minéraux des Roches, 1888, p. 240.

†Michel Lévy: Sur la réfringence des auréoles polychroiques: C. R. CXX.

Inclusions. The feldspar of the normal gabbro is nearly always in large grains of irregular outline, which often make up a large part of the rock. It is quite fresh and only rarely shows secondary weathering or metamorphic products. It nearly always contains black opaque dust-like particles scattered everywhere, and occurring, though more rarely, in the other minerals of the rock. These are frequently less abundant or altogether absent about masses and crystals of magnetite, and it is therefore inferred that they are fine particles of that mineral. The black acicular inclusions* so often found in gabbros from all párts of the world are sometimes lacking, as they also often are in the plagioclasytes; but they are more frequently present, without however being accompanied by the colored squares and plates, denominated "microplakites" and "microphyllites" by Schrauf, which are probably the sole and efficient cause of the iridescence for which certain labradorites are famous. Liquid inclusions are comparatively uncommon. As noted before all the other original minerals occur more or less commonly as inclusions in the feldspar, though the olivine is very often not in direct contact with the plagioclase, on account of intervening rims of augite.

The pyroxene very often shows the inclusions so well known in bronzite, and probably identical in nature with those occurring in diallage and also in labradorite. They are most abundant along the secondary diallagic parting parallel to *p*(001), or rather parallel to this plane, as they sometimes occur when no trace of the parting can be found. Their direction taken as a whole is parallel to *p*(001), though the individual inclusions are often perpendicular to this plane. They also occur parallel to *h*'(100), and scattered irregularly throughout the pyroxene, in the latter case having no definite orientation.

The origin of these inclusions has been frequently discussed; Kosmann and Trippke believe that they are infiltration products; Judd makes them the basis of his theory of schillerization, considering them to be due to the action of liquids (chiefly water) at great depth and under pressure. He considers that certain planes under strain would act as planes of easiest alteration, or "solution planes," along which negative

*A further study of these inclusions will be found in the chapter devoted to the plagioclasyte.

crystals would first develop, soon to be filled more or less completely by liquids, or more commonly by various hydrous oxides, derived from the enclosing mineral, except in certain exceptional cases, as, for example, those occuring in labradorite. Rosenbusch and Williams* on the other hand consider them to be of primary origin. Bayley†, studying the gabbros of Minnesota, decides that these inclusions are of secondary origin and due to the action of schillerization, basing his opinion on two observed facts, viz: first, the inclusions often occur in certain zones which polarize in different tints from those shown by the other parts of the pyroxene, and, second, the pyroxene immediately surrounding the inclusions "seems to be more changed from its original condition than portions of the same lamellæ at a greater distance from them." These facts will be questioned by no one who has examined a number of thin sections of the rocks in question. But the interpretation of the facts is a different matter. Bayley argues that both facts indicate that the inclusions in the process of development have absorbed some of the material of the surrounding pyroxene, and thus changed its appearance and optical properties. Now, the lamallæ truly polarize in different tints, but that is not all—they extinguish at a distinctly different angle. What more can be said of true twinning? Furthermore, the twinning is not inseparably associated with the inclusions; it occurs where no inclusions can be seen, and on the other hand inclusions occur which cause no such twinning. (See plate XVII., figure 1.) The association of the twinning with the inclusions is not an extraordinary occurrence; on the contrary it is very often noted in pyroxenes, and is usually attributed to the fact that the mere presence of such inclusions at a time when the rock was under pressure could undoubtedly determine the formation of twinning.

It has been said that the mineral seems to be "changed from its original condition" about the inclusions. This is only true in the sense that the area immediately around the grains is clearer and more transparent than those portions further removed. An attentive examination with the highest powers will show that the cause of this appearance is that the mass of

*G. H. Williams: Amer. Jour. Sc. 1886, XXXI, p. 31.
†W. S. Bayley: Jour. Geol. 1893, I, p. 703.

the pyroxene is filled with very fine particles similar in all respects to the larger lamellar inclusions, whereas the area immediately about the larger inclusions contains no such particles. Such a condition is clearly not incompatible with the idea of a primary origin for the inclusions; indeed every thin section of holocrystalline rocks shows analogous phenomena; it will only be necessary to mention the way in which apatite crystals grow to a size out of all proportion to the amount of phosphoric acid contained in a rock. This is an extreme case; most minerals possess the power of attracting to themselves, when crystallizing in a magma, the elements necessary to continue their growth in a much less marked degree. And in the case before us the power of attraction is evidently very weak since it is only exercised through such small distances as one or possibly two hundredths of a millimeter.

Therefore we must conclude that there is no good evidence showing that these inclusions are not primary, while the fact that inclusions of very similar nature are sometimes of primary origin, as elsewhere shown*, lends probability to the belief that these have the same origin. This conclusion is supported by the fact that the inclusions are very rarely limited by planes of the surrounding pyroxene, but are usually wholly irregular in outline, though they also occur with outlines (e. g. hexagonal) manifestly peculiar to themselves.

Olivine alters so universally and in so many different ways that it is extremely difficult to distinguish the primary inclusions from the alteration products. The former seem to be decidedly rare; however liquid inclusions occur very uncommonly, and certain magnetite crystals have presented the appearance of primary inclusions; although, of course, much the greater part of the included magnetite is undoubtedly secondary.

No primary inclusions have been noted in the magnetite. The apatite contains occasional grains of a black opaque mineral, doubtless magnetite; liquid inclusions also occur, though not commonly.

Alterations. The gabbro is in general very slightly altered; it is for this reason that it is possible by its study to obtain clear conceptions of the true original character of a newly

*See Chapter IV. (inclusions in labradorite).

formed gabbro. For the same reason no better material can be found for the study of the beginnings of alteration of many kinds.

The labradorite of the gabbro is found occasionally altering to calcite, which is usually accompanied by the appearance of very finely granular quartz. This alteration is due to the action of filtering water, charged with carbonic acid and may begin anywhere in the crystal; once begun it gradually extends outward irregularly in all directions. But one center of alteration is never much developed before others appear elsewhere in the mineral, to continue in the same way. This secondary calcite sometimes contains numerous opaque black inclusions which are so exceedingly minute as to be wholly indeterminable. It is supposed that they are magnetite particles, and they may represent a part of the material of the numerous acicular magnetitic inclusions of the unaltered feldspar. These magnetite needles, however, probably contribute a large part of the iron entering into the secondary penninite which is often formed at the same time. The latter is developed generally by the same method as the calcite, that is, it originates at various points anywhere in the feldspar and spreads irregularly outward.

The labradorite often alters to a sericitic mineral which it has been impossible to determine absolutely. From the frequency with which muscovite is found as an alteration product. even in basic rocks, it might be supposed to be a true fibrous sericite; but paragonite or even margarite would be a more natural decomposition product of a basic plagioclase. The optical properties of these minerals are nearly identical and when in a finely fibrous condition they can not be distinguished unless they occur in masses large enough to permit chemical, or, at least, microchemical examination. The alteration may commence anywhere in the labradorite, but is especially apt to be found where other alteration has already begun. It has a marked tendency to develop considerably in a few areas rather than form new centers of alteration. This alteration is called "damouritization" by Lacroix*.

Flakes of green pleochroic hornblende also occur included within the labradorite. They are undoubtedly secondary products.

*Lacroix: Minéralogie de la France. Vol. II, 1897, p. 14.

Finally there is one other secondary mineral that is formed at the expense of the feldspar that I have found only in this rock. Its description follows:

Pectolite was first correctly determined by von Kobell in 1828 on material from the Tyrol. It is monoclinic and nearly isomorphous with the pyroxene, wollastonite. Nevertheless the constant notable content of water has caused it to be grouped frequently with the zeolites. At the present time it is generally recognized as a pyroxene, or a mineral closely allied to that group. It occurs in minute lamellæ and fibers, often assuming nearly the spherulitic habit. The mineral possesses two marked cleavages parallel to $p(001)$ and $h^1(100)$ respectively, making an angle of about 85°.

Inasmuch as pectolite has not heretofore been described as a direct decomposition product of feldspar,* though its ordinary mode of occurrence is in cavites or seams in basic igneous rocks, a careful statement of the diagnostics relied upon for its determination will not be out of place.

The mineral is found in the olivine gabbro from Birch lake (1136) occurring as an indubitable alteration product of the labradorite. It is frequently associated with the other alteration products such as calcite and penninite, and seems to be due like them to the action of percolating waters. It occurs by preference in those areas where the labradorite has been slightly fractured by some strain. It rarely occurs on the outside of the feldspar grain, usually being found along some cleavage or fracture line. The mineral is transparent and colorless by transmitted light; by reflected light it gives the whitish color so commonly seen on acid feldspars which are altering to kaolin. As mentioned above it is eminently fibrous, the fibers interlaced with their axes making very small angles with one another. Such a structure produces a hazy changeable extinction, familiar through its frequent occurrence in the fibrous zeolites. This fact, together with the exceedingly small size of the lamellæ—for, fortunately, the fibers sometimes develop into lamellar habit—render the determination of the optic properties a matter of great difficulty. In-

*A transformation entirely analogous, however, has been described by Lacroix: (Minéralogie de la France: II, p. 46). It is the alteration of anorthite to wollastonite.

deed even with the immersion objective (Nachet No. 7) the position of the optic axes was determined only after long and careful search. It is, however, readily determined that the elongation of the fibers is always positive and that the refringence is always notably higher than that of the labradorite. The fibers rarely, if ever, attain the thickness of the section, and are usually less than half that thickness; nevertheless, it is safe to assert that the birefringence is at least .030. The zeolitic extinction of the mineral prevents an accurate determination of the extinction angle of the fibers; but it is clearly never higher than three or four degrees, and may be always zero.

The only rock-forming minerals known to the writer which possess all the characters enumerated above are pyrophyllite, talc, certain micas and pectolite. In all these minerals n_p ($=\mathfrak{a}$) is nearly perpendicular to the easy cleavage p(001), but the optic angle is very distinctive for each one, thus 2E in talc is 15° to 20°; in muscovite it is rarely less than 50° and never more than 75°; in pyrophyllite it is 105° to 110°, while in pectolite it is 143°, being in the last case the value of the apparent obtuse optic angle, since pectolite is positive. A section was finally found very nearly parallel to the easy cleavage, and at the same time large enough to give a good interference figure.

The figure obtained was a distinct bisectrix distant about two-thirds of the radius from the center of the field, but showing that the section was strictly perpendicular to the optic plane. The quartz and mica plates both showed the section to be perpendicular to n_p ($=\mathfrak{a}$) which must be the obtuse bisectrix since the hyperbolas leave the field very promptly. Indeed the angle between the tangent positions of the hyperbola on the two sides of the field is only about 33° in spite of the fact that the obliquity of the section must increase this angle. Therefore the mineral is positive and must be pectolite.

It is unfortunate that the mineral does not occur in sufficient quantity to make a chemical analysis possible; but even microchemical tests are utterly out of the question. The chemical changes necessary for such a transformation are readily seen to be the elimination of the alumina with a notable decrease in the silica.

The beginning of the alteration of the pyroxene is often

marked by the appearance of diallagic parting planes which always appear first on the outside of the crystal and develop inward. In their characteristic development the parting lines are very fine and close together, but they seem to occur rarely as a series of coarse fracture lines similar to the coarse pyroxenic cleavages, being merely more irregular. The augite sometimes passes through the diallage stage before altering to other minerals, but about as frequently alters directly to chlorites, micas, hornblendes, etc.

Chloritization of the pyroxene is very common. The pale green chlorite fibers usually appear first about the edges of the augite, but rapidly propagate themselves along the cleavage and fracture lines. The pyroxene may thus be wholly transformed to a mass of fibrous penninite or clinochlore, or, more rarely delessite*.

Uralitization is not uncommon, and the resultant hornblende is sometimes brown, and sometimes green. It may be either fibrous, or distinctly more compact, and lamellar. It is always pleochroic.

It is uncommon to find the pyroxene altering directly to biotite, without the evident coöperation of the feldspar. The formation of the mica is therefore usually in the nature of a "reaction" between two minerals, and one of these two is always labradorite, while the other is oftenest magnetite, but may also be augite, or, more rarely, olivine. The biotite occasionally occurs, however, in fibers, along the fractures of pyroxene while the surrounding feldspar is wholly unaltered; in such cases it is evident that the mica is the result of the alteration of the augite alone.

Finally, all these various methods of alteration of the pyroxene are often accompanied by the separation of grains of iron oxide, indicating that the augite was originally highly ferriferous. These grains are usually magnetite, but also occur as hematite.

The serpentinization of the olivine is an alteration so well known that it is only needful to state that the resultant mineral is bowlingite much oftener than antigorite. The former fre-

*This mineral has not been observed by the writer, but is a common mineral in the lake Superior region, and is noted as a decomposition product of augite by Bayley. See Bayley: Op. cit. Jour. Geol. I, 1893, p. 704.

quently orients itself upon the olivine; in such cases a single crystal of bowlingite is formed from a single crystal of olivine; at other times the alteration mineral is finely fibrous, and has all possible orientations, and zeolitic extinction. It is not rare to find a crystal of olivine altering to both the fibrous and the compact types. Bowlingite varies in color from green to brown according to the condition of oxidation of the iron; and is nearly always pleochroic. The bowlingite is only rarely seen to form away from the olivine and then only at very short distances away, but antigorite occurs filling all the fractures of the labradorite all the way from one olivine grain to another. If any cavity occur, it is also often filled with antigorite. (See Plate VIII, Fig. 1.) Chrysotile and xylotile perhaps occur, but they have not been identified by the writer.

The only other alteration of the olivine which has been observed is to biotite. This is comparatively quite rare. The biotite often starts as a decomposition product of the pyroxene, and extends into the olivine; in other cases it is a "reaction" product to which both the feldspar and olivine contribute some elements; finally it seems to occur occasionally from the direct alteration of the olivine alone.

Magnetite is often seen surrounded by a zone of biotite, and this is the commonest source of the brown mica of the rock. The biotite is evidently in such cases the result of the simultaneous alteration of magnetite and feldspar, as it never extends away from either.

Leucoxene has never been observed, though the magnetite, at least in certain diabases is known to be titaniferous. In highly altered areas small grains of quartz occasionally occur. They are doubtless derived from the labradorite, though their direct formation from the feldspar has not been observed.

The chemical composition of the normal gabbro varies within rather wide limits; nevertheless analyses from widely separated localities are quite comparable, the differences being readily explained by the comparative abundance of the essential mineral constituents. The specific gravity generally ranges between 2.70 and 3.00. A sample from Birch lake which was analyzed is not quite typical, as it shows a marked tendency toward the ophitic texture. The column I. shows the results obtained, while II. is the average of two analyses

by Dr. H. N. Stokes of the laboratory of the United States Geological Survey on material from the same general region:

	I	II
SiO_2	47.70	46.06
TiO_2	1.80	1.05
Al_2O_3	19.04	18.87
Fe_2O_3	.87	.74
FeO	8.84	11.73
MnO	trace	trace
MgO	8.65	9.73
CaO	8.96	8.53
Na_2O	2.53	2.14
K_2O	.53	.37
H_2O	1.38	1.03
	100.30	100.38
Sp. Gr.	2.89	3.00

I. Olivine gabbro (1136) from Birch lake. No appreciable BaO nor SrO; P_2O_5 not determined.

II. Average of two analyses by Dr. H. N. Stokes: First from S. E. ¼, Sec. 19, 63—9 (near Snowbank lake), and second from Sec. 35, 61—12, near Birch lake. Includes P_2O_5 =.03; NiO =.10; see Bayley: Jour. Geol. 1893, I, p. 714.

Titanic acid seems to be a constant element in the normal gabbro in very notable amount; the alumina is very high and the iron is nearly all in the protoxide form. The amount of magnesia is a true index of the relative abundance of augite and olivine. Phosphoric acid is in extremely small amount.

Chapter II. Normal Diabase.

The term diabase is employed in this article to designate a rock identical with a gabbro in its mineralogical composition, but possessing a texture distinctly ophitic instead of the granitic texture of the gabbros. Like the olivine-free gabbros the normal diabases (containing no olivine), are rare in Minnesota; the rock to be studied here contains a small amount of chrysolite. Strictly speaking, it is therefore an olivine diabase, but in its chemical composition it differs less from the diabases absolutely free from olivine than from those containing the ordinary quantity of chrysolite, such as the rock forming the

subject of the next chapter. In the latter and in the normal diabase the texture is identical, both showing all gradations from a very coarse ophitic texture tending to become granitoid through medium grained ophytes and porphyrytes to the finest diabasic, and sometimes porphyritic basalts, without, however, usually containing a glassy residue. The intrusive character of the diabases was first distinctly announced by Lawson* whose views on this point are now generally accepted. The intrusive sheets are usually nearly flat and vary greatly in thickness, from a meter to one hundred meters or even more. They always present a striking subcolumnar structure at right angles to the plane of their extension, and form a prominent feature of the topography of northeastern Minnesota. These sheets, termed by Lawson "Logan sills" are especially common in the region around Pigeon point where they are found interbedded with Keeweenawan as well as Animikie formations. They are of the nature of horizontal dykes derived, according to N. H. Winchell† from the gabbro magma. Their composition is certainly not opposed to this view since both mineralogically and chemically they are practically identical with the gabbro.

But diabases in northeastern Minnesota are not restricted in occurrence to these Logan sills. They occur also in numerous dykes and in masses of irregular shape. They occupy large areas as the country rock (see the map), and have been shown to belong to at least two different epochs. Still another category of diabases can be attributed to merely local variations of the ordinary gabbro, where the latter has cooled more rapidly than the main mass. In such cases the diabase is always very coarse and may show passages to true gabbros. (See plate IX, figure 1.) To this category must be attributed the diabase studied here; it comes from near the northern border of the gabbro area, and it was perhaps the contact which caused slightly more rapid solidification. Nevertheless the type presents no evidence of the slightest modification other than the change of texture; in mineralogical and chemical composition it is entirely comparable to the normal gabbros.

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*A. C. Lawson: The laccolitic sills of the northwest coast of lake Superior. Geol. Nat. Hist. Surv. Minn. Bull. No. 8, 1893, p. 24.

†N. H. Winchell: Geol. Nat. Hist. Surv. Minn. Final Rep., Vol. IV.

The diabase is of a mottled gray color often slightly greenish; the ophitic texture passes occasionally into a porphyritic-ophitic texture by the appearance of labradorite phenocrysts, whose polysynthetic twinning on cleavage surfaces is quite conspicuous. Dark green to black augite is abundant and magnetite never fails, though it is sometimes only sparsely disseminated. Olivine is rarely entirely wanting.

On decomposition the rock usually becomes darker, as fibrous and compact hornblende appear and biotite forms in bright lamellæ.

Under the microscope the ophitic *texture* is at once seen, the labradorite usually occurring in lath shaped forms, having crystallized before the pyroxene. Nevertheless the grain is so coarse and the labradorite so abundant that such rocks have repeatedly been called gabbros by writers on the petrography of northeastern Minnesota. The order of crystallization is: apatite, magnetite, labradorite, pyroxene. If any olivine occurs, its period of crystallization is in general later than that of the labradorite, as is shown by the numerous crystals of feldspar projecting into the olivine, but exceptions to this rule are not lacking. Pyrite can occasionally be found in very small amount, which crystallized about the same time as the magnetite, being often enclosed within the augite and labradorite.

The *minerals* of the normal diabase differ in scarcely any respect from those of the olivine diabase which will be described in detail in the next chapter. The labradorite varies in composition between $Ab_3 An_4$ and $Ab_2 An_3$. The pyroxene has a very slight pleochroism in the greenish and pink tints, very similar to the colors of the abnormal pyroxene of the olivine diabase from Pigeon point; but the pyroxene of the typical diabases seems to be normal augite. Olivine is always in much less quantity, and may even lack entirely in these types. Magnetite, apatite, and pyrite present no special characters. The commonest minerals of secondary origin are: biotite, hornblende, penninite, muscovite and calcite.

Inclusions—The labradorite frequently contains minute black dust-like inclusions as well as opaque black needles. "Microplakites" and "microphyllites" have not been observed, nor has any iridescence appeared. Liquid inclusions occur rarely.

The augite often contains inclusions apparently identical with what Schrauf has named microphyllites and microplakites in labradorite. They will receive further study later. Liquid inclusions have not been observed in augite, though they have been found rarely in the olivine, and in the apatite.

The *alteration* of the labradorite is both endogenetic* and exogenetic*. It results most commonly in the production of penninite, calcite and a sericitic mineral, probably muscovite.

The augite alters to biotite both brown and green, as well as to hornblende and chlorite with frequent attendant separation of magnetite. Occasionally the iron seems to separate out as pyrite. Hematite may be formed any where in the rock.

Biotite is oftenest formed by mesogenesis between the magnetite and the labradorite.

The *chemical composition* of the normal diabase is given below. The titanium is undoubtedly mostly contained by the augite, which is slightly pink in thin section, and by the magnetite. The water is low corresponding to the slight decomposition which the rock has suffered.

	I
SiO_2	47.90
TiO_2	.57
Fe_2O_3	19.92
FeO	9.78
MnO	trace
MgO	4.55
CaO	8.56
Na_2O	2.75
K_2O	.56
H_2O	.76
	100.39

Specific gravity........2.93

I. Diabase from east side of Birch lake (954). (The specimen is poor in olivine.) No appreciable BaO nor SrO; P_2O_5 and CO_2 not determined.

*The definition of these terms will be given in chapter IV.

Explanation of Plates.

Plate VIII.

Figure 1. Olivine gabbro (1136) from Birch lake. Coarse granular texture. A cavity in the labradorite (3) filled with antigorite (13), derived from the olivine of the rock. Crossed nicols x 100.

Figure 2. Olivine gabbro (1136) from Birch lake. Pegmatitic intergrowth between labradorite (3) and augite (6), and also between magnetite (10) and augite (6). A large mass of olivine (9) is occasionally xenomorphic toward the feldspar. Biotite (5) has been formed by mesogenesis. Crossed nicols. x 100.

Plate IX.

Figure 1. Normal diabase (954) from Birch lake. A single anhedron (3′) of labradorite twinned according to the four laws: Baveno, Carlsbad, albite, and pericline, but the last type is not visible in the position photographed. The large labradorite crystals are separated by stringers of twinned pyroxene (6). Crossed nicols. x 100.

Figure 2. Olivine diabase (1843) from Pigeon point. Ophitic texture very distinct. Labradorite (3), pyroxene (9), olivine (6), and bowlingite (14). Crossed nicols. x 75.

Plate X.

Figure 1. Plagioclasyte (336E) from Carlton peak. Augite (16) surrounded by magnetite (10), and by satellites of augite, oriented on the principal pyroxene mass. A large automorphic crystal of magnetite (10), decaying labradorite (3), and fibers of zeolites (19) colored by hematite also occur. Natural light. x 100.

Figure 2. Plagioclasyte (336E) from Carlton peak. Rectangular alteration of labradorite. This alteration is endogenetic, and results in the formation of zeolites, and, later, calcite, zoisite, hematite, etc. Natural light. x 100.

Plate XI.

Figure 1. Silicoferrolyte (960) from Birch lake. Magnetite (10) encloses, in poikilitic texture, fayalite (9), augite (6), and quartz (1). Crossed nicols. x 100.

Figure 2. Orthoclase gabbro (1797) from Duluth. Orthoclase (2) surrounds and traverses the labradorite (3), which encloses crystals of augite (6) and apatite (11). Crossed nicols. x 100.

Plate XII.

Figure 1. Cordierite noryte (983) from Sec. 15, T. 63-9. Poikilitic texture. Quartz (1), labradorite (3), cordierite (4), anomite (5), bronzite and enstatite (8), and anthophyllite (15). Crossed nicols. x 100.

Figure 2. Quartz gabbro (854G) from near Little Saganaga lake. Very small rutile crystals in groups, in penninite (12). Secondary calcite (16). Secondary quartz in the edge of the chlorite oriented on the magmatic quartz (1), forming an "enlargement." Crossed nicols. x 100.

Plate XIII.

Graphic representation of the chemical composition of the rocks studied by the method of Michel Lévy. SiO_2 expressed in figures: Al_2O_3 not directly expressed, unless in excess which=a; Fe_2O_3=f': FeO=f; CaO, feldspathisable,=c; CaO in excess=c'; Na_2O=n; K_2O=k.

Figure 1. Silicoferrolyte (960) from Birch lake.
Figure 2. Troctolyte (514) from near Duluth.
Figure 3. Olivine gabbro (1136) from Birch lake.
Figure 4. Normal diabase (954) from Birch lake.
Figure 5. Orthoclase gabbro (1797) from Duluth.
Figure 6. Olivine diabase (1843) from Pigeon point.
Figure 7. Plagioclasyte (336E) from Carlton peak.
Figure 8. Cordierite noryte (983) from Sec. 15, T. 63-9.
Figure 9. Quartz gabbro (854G) from near Little Saganaga lake.
Figure 10. Pyroxene from olivine diabase (1843) from Pigeon point.
Figure 11. Labradorite from plagioclasyte (336E) from Carlton peak.
Figure 12. Pseudomesolite (with H_2O omitted) from plagioclasyte (336E) from Carlton peak.

Plate XIV.

Graphic representation of the chemical composition of the rocks by the method of Brögger.

Figure 1. Average of olivine gabbro (1136), diabase (954) and olivine diabase (1843).
Figure 2. Plagioclasyte (336E).
Figure 3. Quartz gabbro (854G)
Figure 4. Silicoferrolyte (960).
Figure 5. Cordierite noryte (983).
Figure 6. Troctolyte (514).
Figure 7. Orthoclase gabbro (1797).

Plate XV.

Graphic representation of the chemical composition of the rocks by the method of Becke. Si is located by the sign □; Al, by the sign ×; Fe, by the sign ■: and Mg, by the sign +; Ca, Na, and K determine the position of the basal point in the "horizontal field" (lower figure). 1. Silicoferrolyte (960); 2. Troctolyte (514); 3. Olivine

gabbro (1136); 4. Diabase (954); 5. Orthoclase gabbro (1797); 6. Olivine diabase (1843); 7. Plagioclasyte (336E); 8. Cordierite noryte (983); 9. Quartz gabbro (854G).

Plate XVI.

Graphic representation of the chemical composition of the rocks by the method of Iddings. SiO_2 of feldspathic elements=s; SiO_2 of ferromagnesian elements=s'; Al_2O_3 of feldspathic elements=a'; excess of alumina=a; Fe_2O_3+FeO=f; MgO=m; CaO of feldspathic elements=c; excess of CaO=c'; Na_2O=n; K_2O=k. 1. Silicoferrolyte (960). 2. Troctolyte (514). 3. Olivine gabbro (1136). 4. Diabase (954). 5. Orthoclase gabbro (1797). 6. Olivine diabase (1843). 7. Plagioclasyte (336E). 8. Cordierite noryte (983). 9. Quartz gabbro (854G).

Plate XVII.

Figure 1. Olivine gabbro (1136) from Birch lake. Magnetite (23), automorphic toward augite (11), which is apparently automorphic toward olivine (20). x 60.

Figure 2. Olivine gabbro (1136) from Birch lake: inclusions in the pyroxene (11) containing no twinning; the alteration to biotite (10) commences in the pyroxene, but continues in the olivine (20); further, biotite is formed by mesogenesis, between the labrodrite and the pyroxene and between the olivine and the labradorite (3). x 60.

Figure 3. Apatite surrounded by a halo in biotite of the olivine gabbro (1136). Apatite $n_g > n_m$ biotite. x 300.

Figure 4 "Polysomatic" texture in pyroxene from Pigeon point. No difference in the color of the different areas. x 120.

Figure 5. Pleochroic halo in clinochlore about magnetite (?) The halo consists of two bands, the inner one being nearly colorless. In olivine diabase from Pigeon point. x 300.

Figure 6. Crystal outlines of allanite found in the gabbro. (1136) from Birch lake. x 550.

Figure 7. Pleochroic halo about allanite in brown hornblende in the olivine diabase (1843) from Pigeon point. Consists of two rings exactly circular, the outer one being much lighter. Both are sharply defined. x 300.

Figure 8. Crystal outline of an unknown mineral, in the plagioclasyte (336E) from Carlton peak. The mineral possesses weak pleochroism, in yellow tints. The crystal is not definitely oriented optically. x 300.

Figure 9. Augite (11) enclosing olivine (20) in the poikilitic texture in the troctolyte (514) from near Duluth. Magnetite (23) is also enclosed by the pyroxene. x 60.

Plate XVIII

Figures 10 and 11. Apatite crystals deeply corroded, in the orthoclase gabbro (1797) from Duluth; the apatite contains many inclusions. It is surrounded by orthoclase, hornblende, and magnetite. x 120.

Figure 12. Corroded and fractured apatite in orthoclase gabbro (1797) from Duluth. The apatite (6) contains masses of orthoclase (1), magnetite (23) and biotite (10), besides many liquid inclusions. It is surrounded by orthoclase and magnetite. x 120.

Figure 13. Crystals of potassium platinic chloride formed by adding chloride of platinum to a solution of the abnormal apatite from the orthoclase gabbro (1797), from Duluth. x 530.

Figure 14. Crystals of sulphate of potassium and bismuth formed by adding bisulphate of bismuth to a solution of the abnormal apatite from the orthoclase gabbro (1797) from Duluth. x 500.

Figure 15. Cavities of unusual form in apatite of the orthoclase gabbro (1797) from Duluth. A. Three ellipses with a common center. B. A double border. C. Two cavities united by a curved canal.

Figure 16. Halo in biotite along the contact between biotite and enstatite, in the cordierite noryte (983) from Sec. 15, T. 63-9. x 100.

Figure 17. Twinning of cordierite, first type; the twinning axis is the vertical axis, and the composition face is M (110). In the figure the part in full lines was drawn with a camera lucida from a section of the cordierite noryte (983) from Sec. 15, T. 63-9. x 300,

Figure 18. Twinning of cordierite, second type; the twinning axis is the vertical axis, and the composition face is g^2 (130). The part in full lines was drawn with a camera lucida from a thin section of the cordierite noryte (983) from Sec. 15, T. 63-9. The figure also shows the change to twinning by interpenetration. x 150.

Figure 19. Orientation of staurolite in cordierite, in the cordierite noryte (983) from Sec. 15, T. 63-9. The figure shows the face h^1 (100) of cordierite and the face g^1 (010) of staurolite. x 250.

Figure 20. Intense halo in penninite about a crystal of zircon. In the quartz gabbro (854G) from near Snowbank lake. The refringence and birefringence are both increased in the halo. x 300.

Figure 21. Magnetite preserving the trace of the cleavages of a pyroxene, now altered to penninite, in the quartz gabbro (854G) from near Snowbank lake. x 60.

Figure 22. Halo in penninite about a mass of rutile needles, in the quartz gabbro (854G) from near Snowbank lake. x 300.

Figure 23. Amorphous bowlingite, still showing the incomplete and irregular form of the original olivine. In the quartz gabbro (954G) from near Snowbank lake. x 60.

[*To be continued.*]

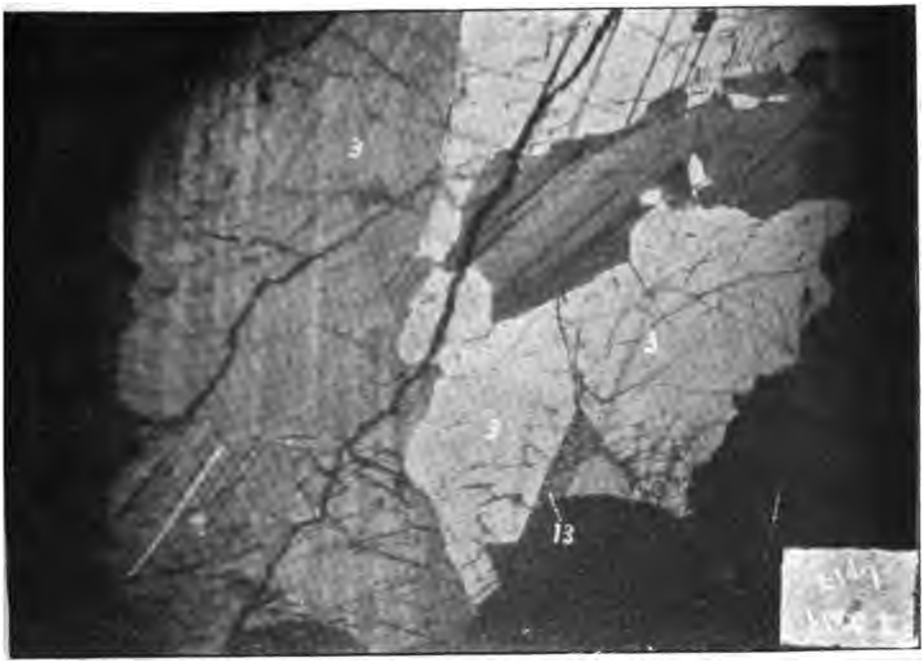


FIG. 1.

FIG. 2.

FIG. 1.

FIG. 2.

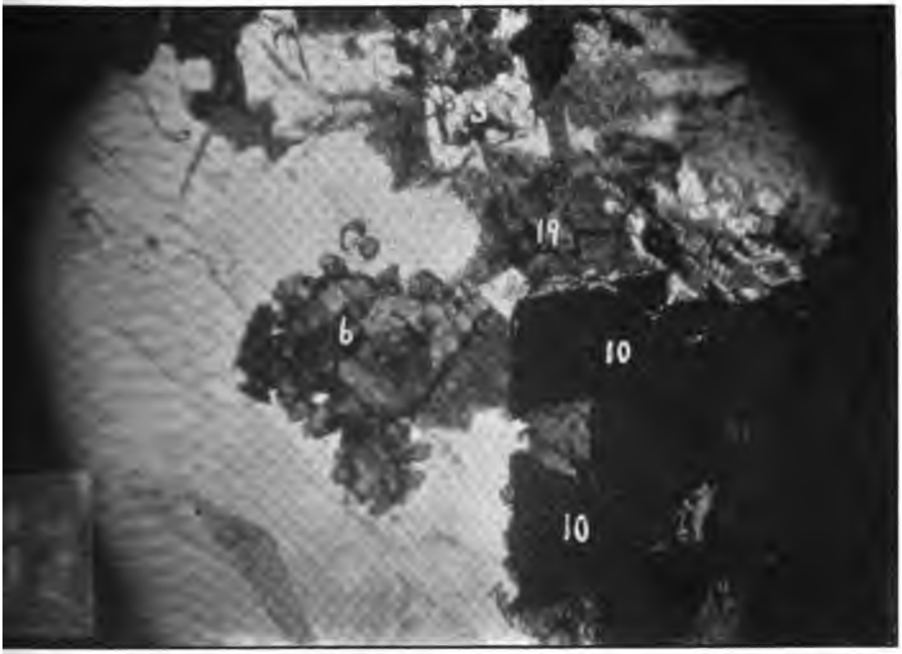


FIG. 1.

FIG. 2.

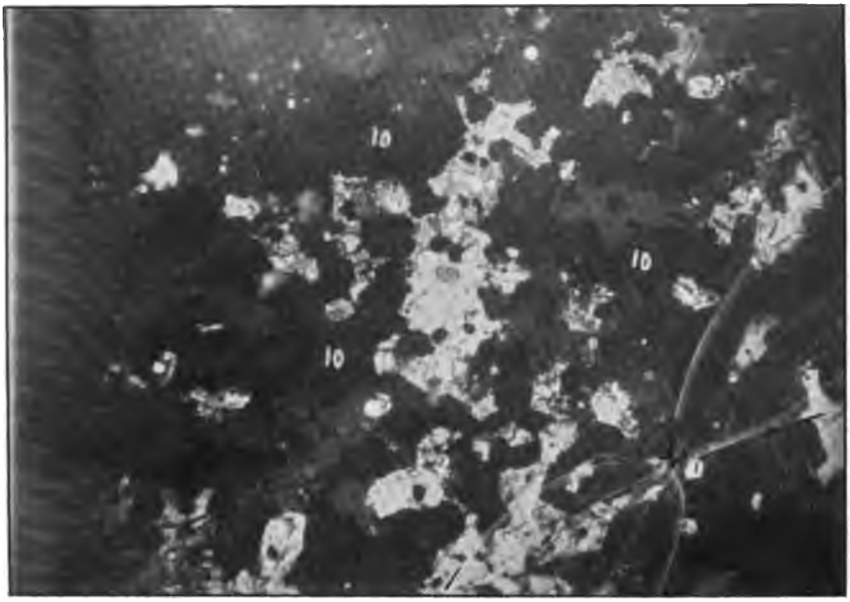


FIG. 1.

FIG. 2.

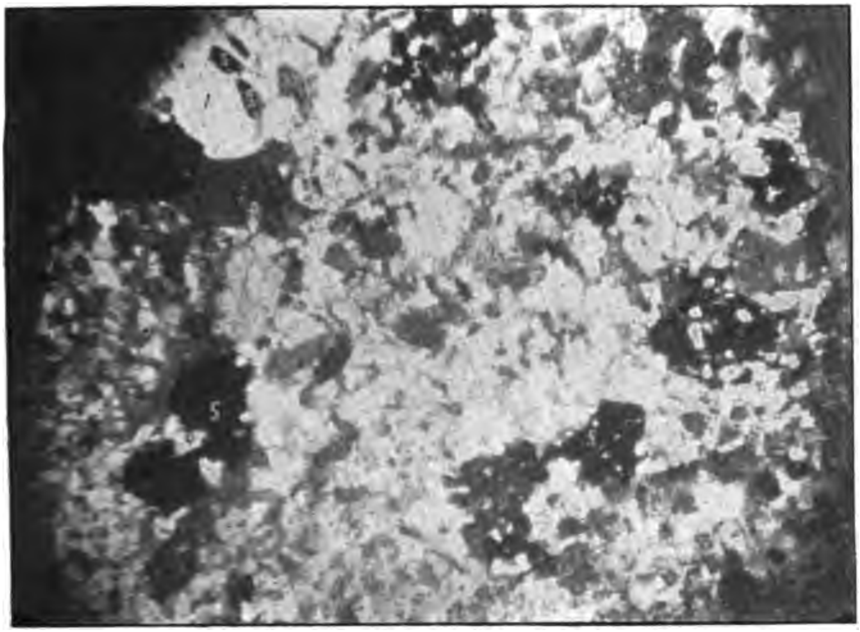


FIG. 1.

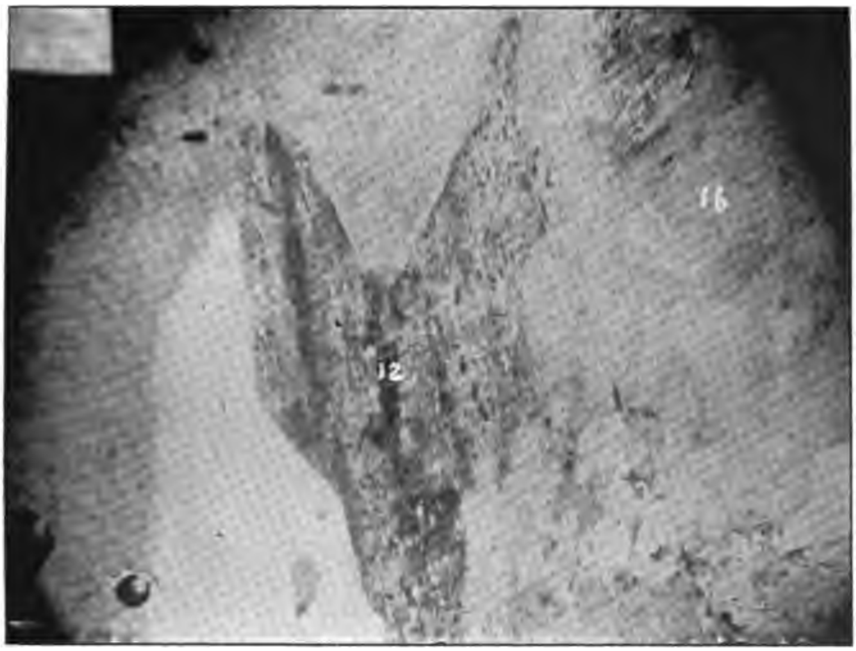


FIG. 2.

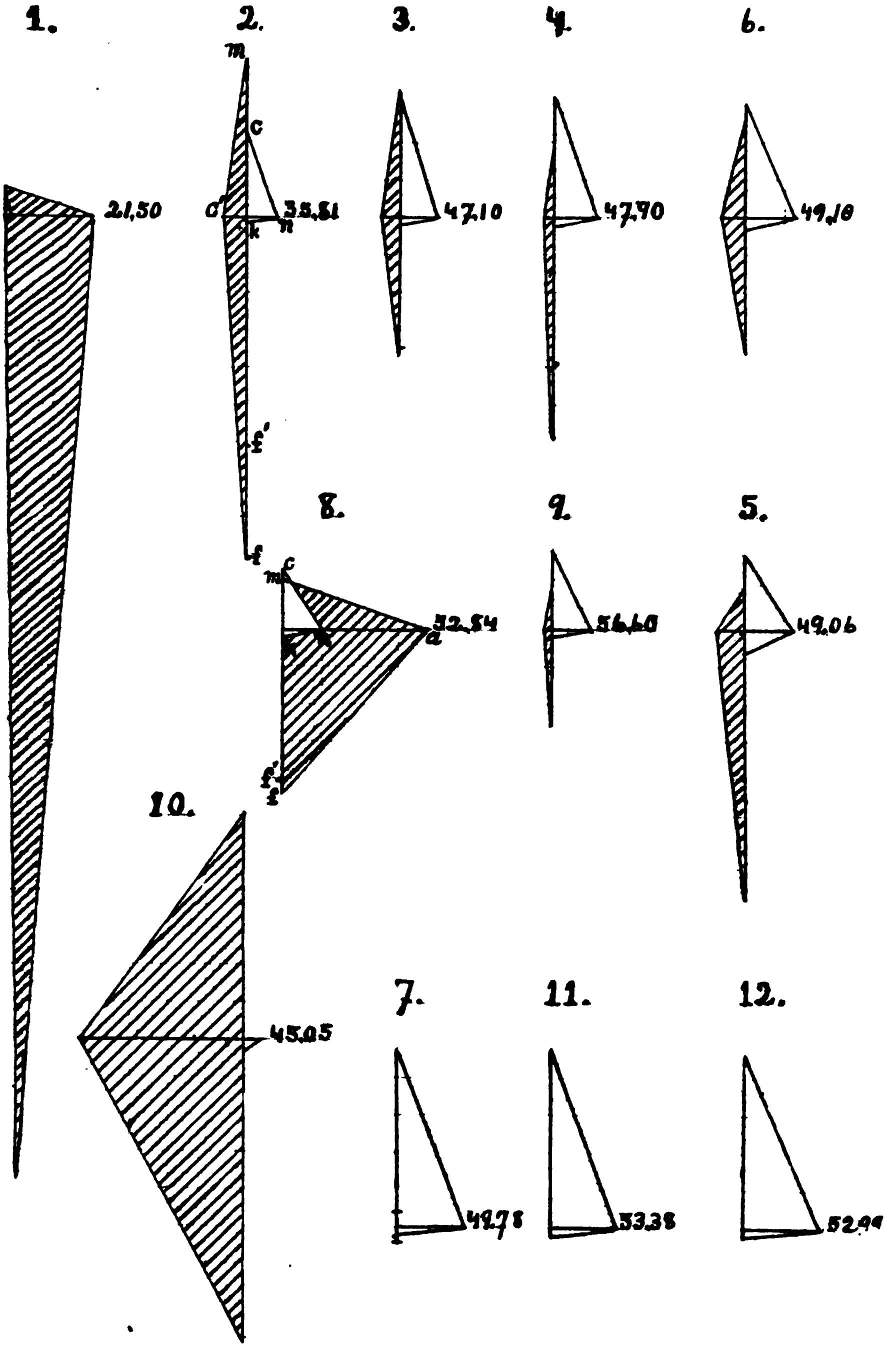
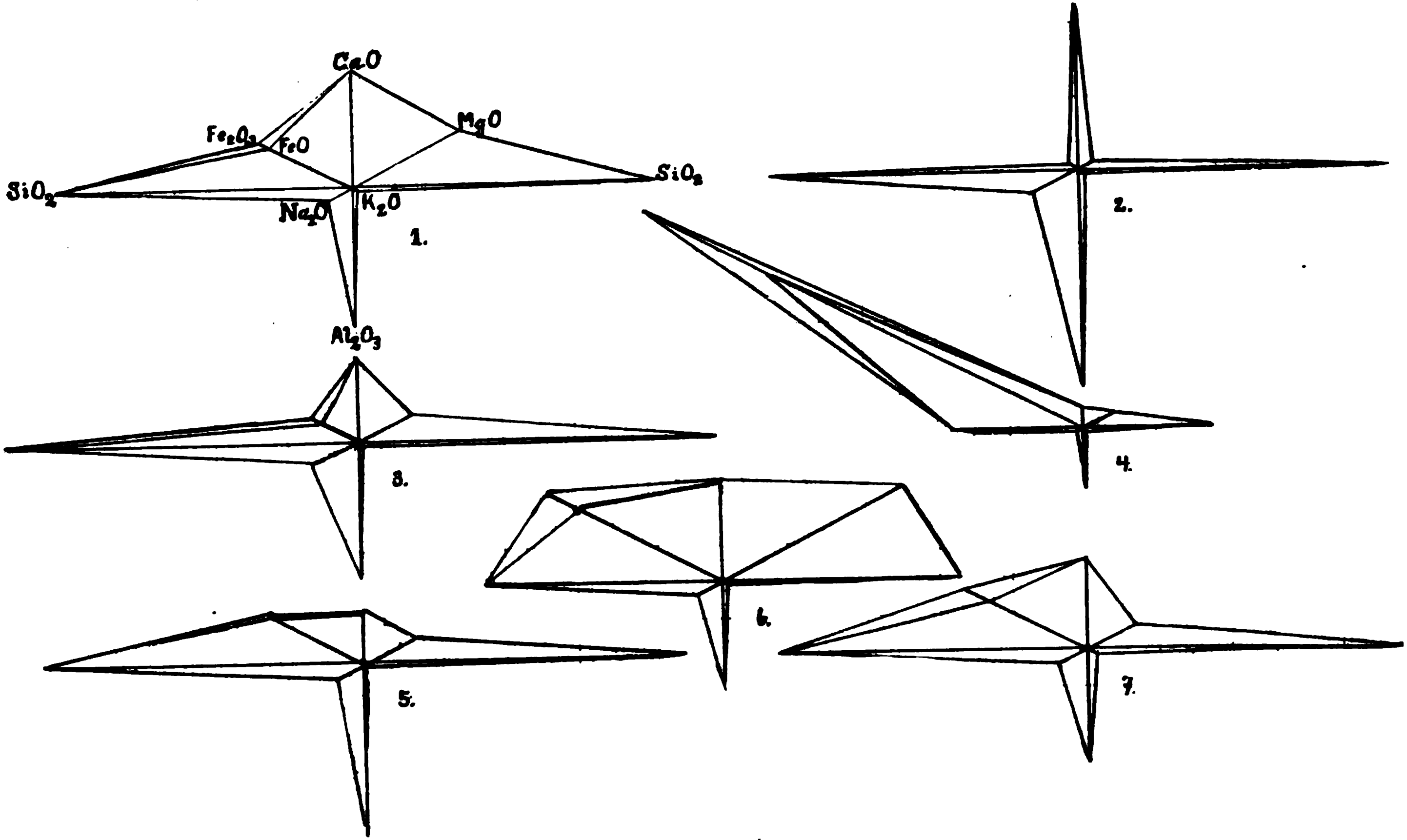
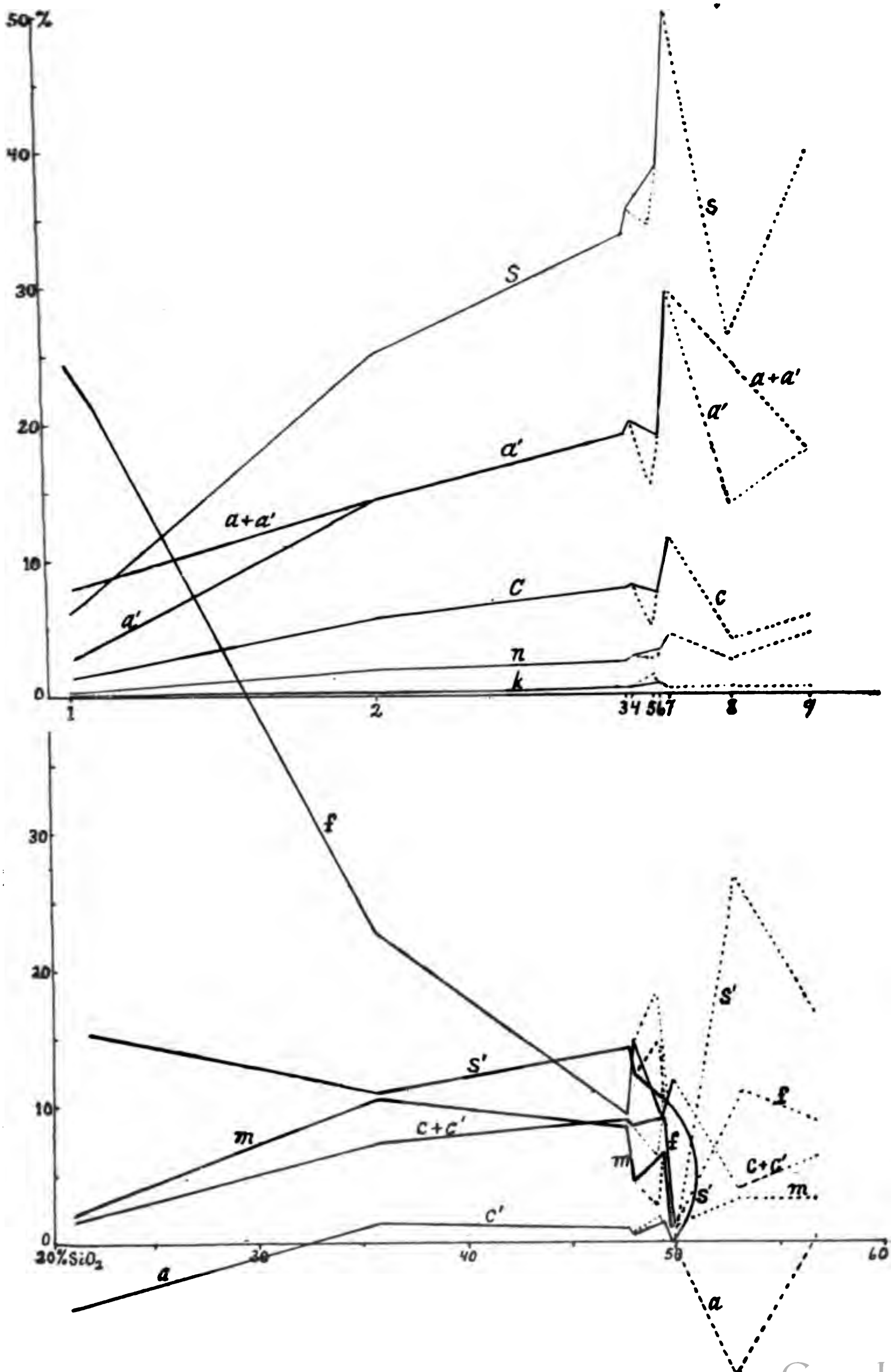
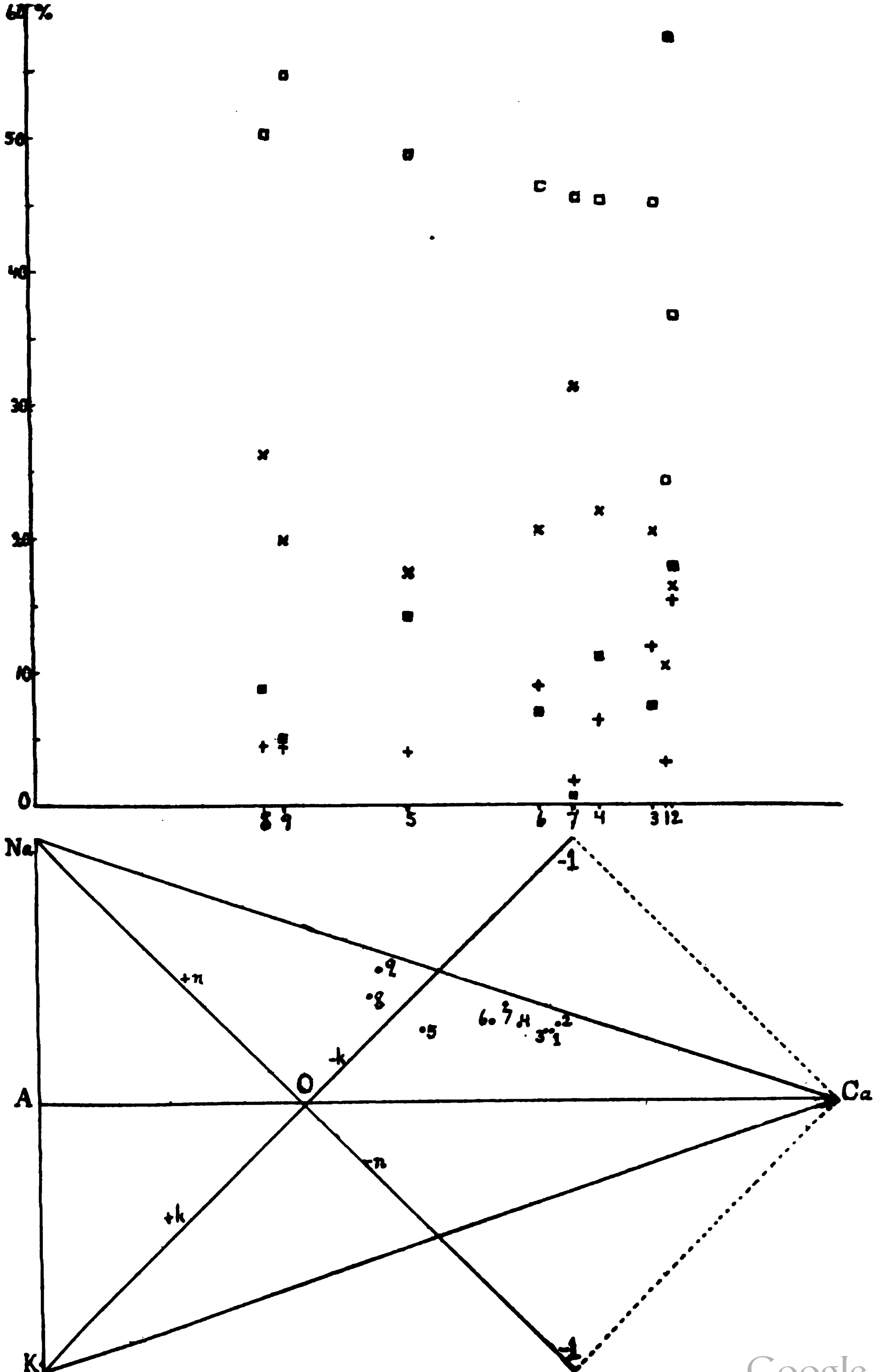

1.
21.50
2.
m
c
c'
k
n
38.81
f'
f
3.
47.10
4.
47.70
6.
49.10
8.
c
m
32.54
a
k
f'
f
9.
56.60
5.
49.06
10.
45.05
7.
11.
53.38
12.

PLATE XIV.




50%
40
30
20
10
0
S
a+a'
a'
C
n
k
f
1
2
3 4 5 6 7
8
9
30
20
10
0
S'
m
c+c'
c'
a
20% SiO_2
30
40
50
60
m.



%
60
50
40
30
20
10
0
8
9
5
6
7
4
3
1
2
Na
A
K
Ca
O
+n
-n
+k
-k

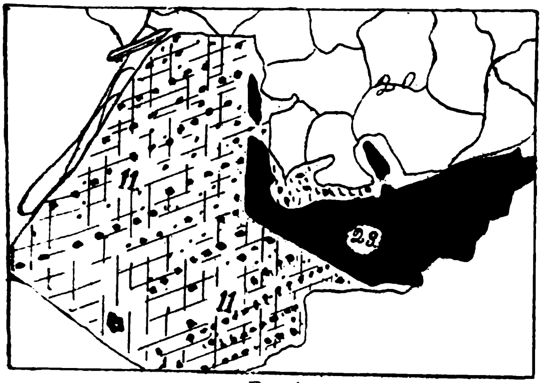


FIG. 1.

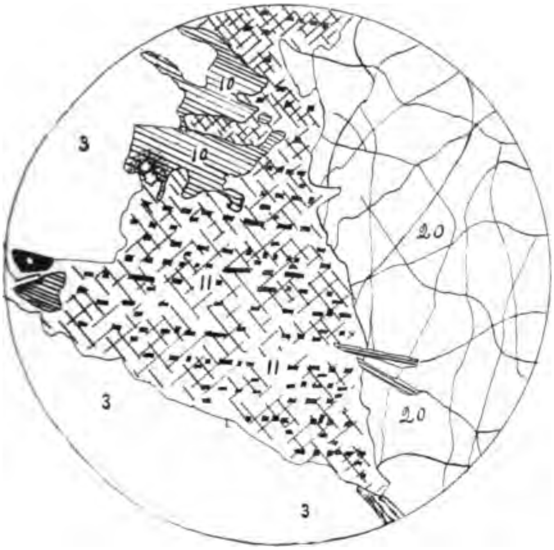


FIG. 2.

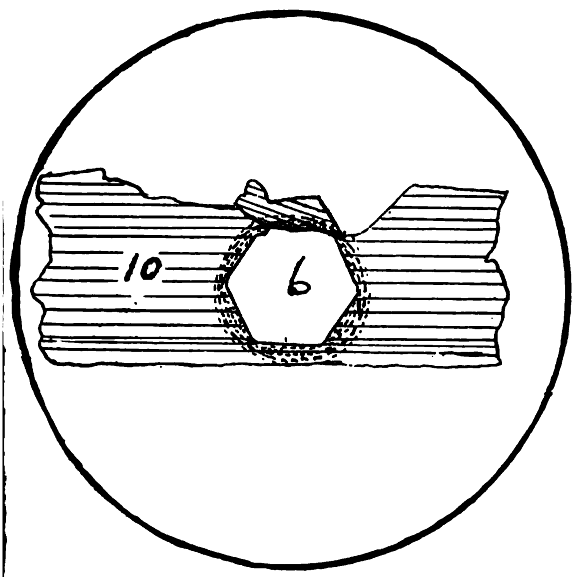


FIG. 3.

FIG. 4.

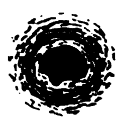


FIG. 5.

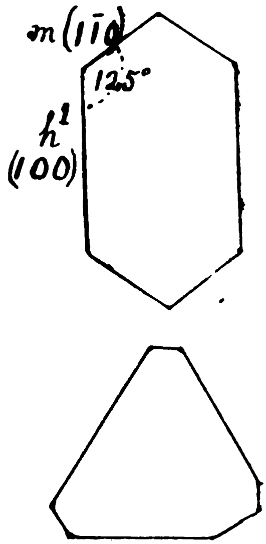


FIG. 6.

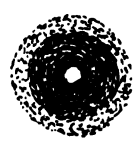


FIG. 7.

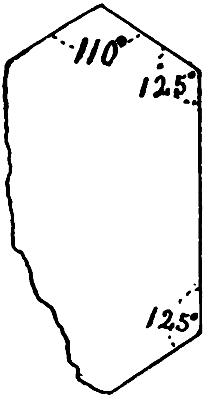


FIG. 8.

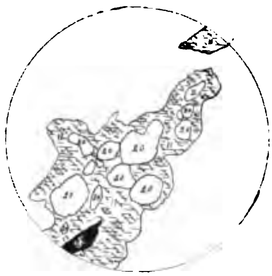
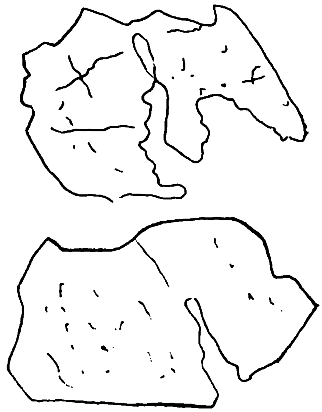


FIG. 9.



FIGS. 10 AND 11.

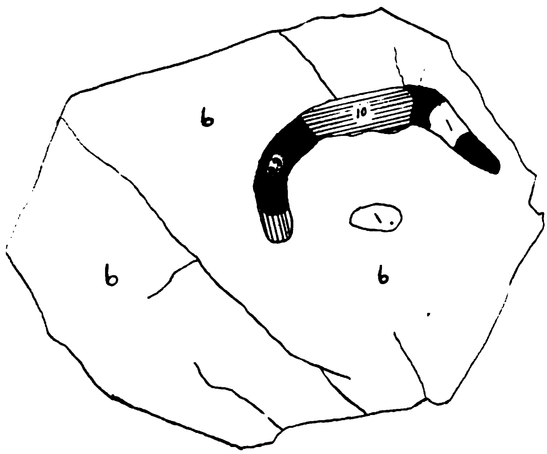


FIG. 12.

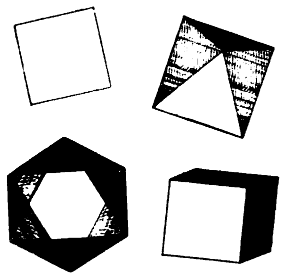


FIG. 13.

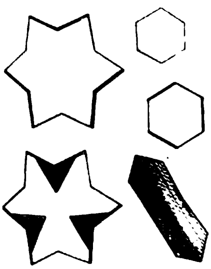


FIG. 14.

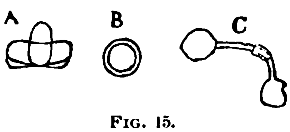


FIG. 15.

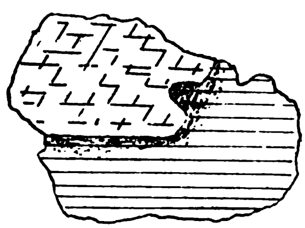


FIG. 16.

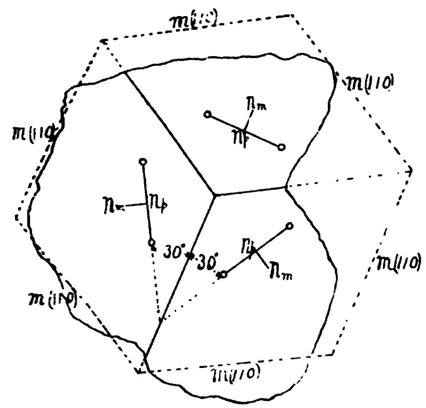


FIG. 17.

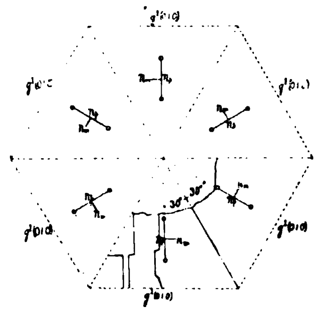


FIG. 18.

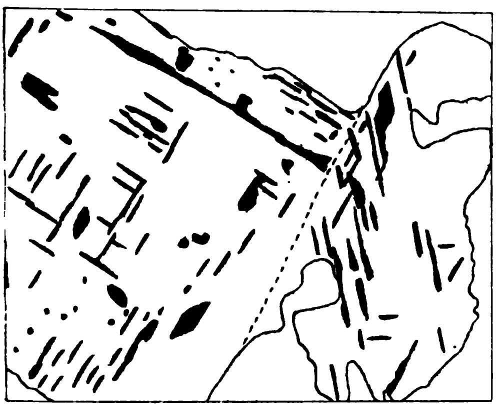


FIG. 21.

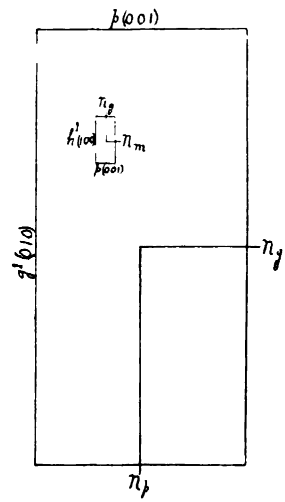


FIG. 19.

FIG. 23.

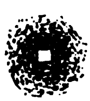


FIG. 20.

FIG. 22.

EDITORIAL COMMENT.

During the spring of 1900 the Director of the U. S. Geological Survey has planned, with the approval of the Secretary of the Interior, an important reorganization of the geologic branch. In order that the significance of this step should be appreciated in all its bearings, it is desirable briefly to review the history of the administration and scientific control within the survey.

In the first annual report, Mr. King set forth a plan of organization based on grand geographic and geologic provinces. The work being then restricted to the national domain west of the 101st meridian, four divisions were established, that of the Rocky mountains under Emmons, that of the Colorado under Dutton, that of the Great Basin under Gilbert, and of the Pacific under Hague. Each of these divisions corresponded to a province within which the geologic phenomena had a certain unity of history and character, and it was wisely argued that the work in each should be directed by a geologist familiar with the special problems of the area entrusted to him. At the same time, the limited appropriations of the survey and the adopted policy of surveying the most important mining districts led to a concentration of effort upon Leadville, Eureka, and the Comstock lode, so that initially comparatively little progress was made in solving the broad geologic problems presented to each division. The principal contributions which the West yielded to the philosophy of the science were made by the surveys through whose consolidation the Geological Survey was created. With the growth of the survey and the addition to its corps of many of the leading minds in American geology, more numerous geographic divisions were established and their limits became more artificial. Thus, in the sixth annual report we find enumerated, in addition to the ones first established, the division of Glacial Geology (Chamberlin), the division of Volcanic Geology (Dutton), the division of the Crystalline Schists of the Appalachian and Lake Superior Regions (Pumpelly and Irving respectively), the Appalachian Region (Gilbert), and the Yellowstone Park (Hague). As divisions became more numerous and restricted, the administrative machinery became

more complex, and the opportunities afforded the geologists in charge to study broad problems became more and more limited. Finally, it was found that the administrative relations were not only difficult but expensive, since they involved the maintenance of independent offices and clerks, and in the interests of economy and efficiency the system of geographic divisions was abolished in 1893. In its place was substituted an organization by parties, of which there were at first twenty and subsequently nearly double that number, each acting independently of the other except in so far as they were all brought into coöperation through the assistant in geology to the director. Broad coördination of scientific work was for the time being subordinated to the accumulation of facts, especially in the form of geological maps, rather than to the consideration of philosophic problems. After six years of this activity in the working out of special problems, the time has come for broader supervision and coördination of work, and to this end the following appointments have been made:

Geo. F. Becker, Geologist in charge of Physical and Chemical Research.

T. C. Chamberlin, Geologist in charge of all Pleistocene Geology.

S. F. Emmons, Geologist in charge of Investigation of Metalliferous Ores.

C. Willard Hayes, Geologist in charge of Investigation of Non-Metalliferous Economic Deposits.

T. W. Stanton, Paleontologist in charge of Paleontology.

C. R. Van Hise, Geologist in charge of Pre-Cambrian and Metamorphic Geology.

Bailey Willis (Assistant in Geology to the Director), Geologist in charge of Areal Geology.

The field of supervision of each geologist in charge is coëxtensive with the work of the geological survey and relates to all parties engaged in work connected with his special subject. His assistance in field or office work may appropriately be offered or invited. His opinion is to be considered authoritative in subjects under his supervision, and his approval to any report may be required. This authority, however, is restricted to the scientific aspects of the work. Administrative direction remains as heretofore wholly in the hands of the

director, and the work of the survey will proceed, after the manner which has been found successful, of authorization of plans of operations after full consideration and conference upon estimates submitted by geologists in charge of parties.

Under the organization now adopted, each geologist is at liberty to make full use of the facts which he observes within his field of operations, the degree of supervision exerted by the geologist in charge of any particular subject to be duly credited in an appropriate manner. For the geologists in charge the plan affords an opportunity to study a special subject in all its aspects throughout the field of operations of the survey, either directly by personal observation or by conference with associates. This opportunity is unequaled in both multiplicity and magnitude of the phenomena presented to each specialist.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Adams, F. D.

On the probable occurrence of a large area of nepheline-bearing rocks on the northeast coast of Lake Superior. (Jour. Geol., vol. 8, pp. 322-325, May-June, 1900.)

Ami, H. M.

Progress of Geological work in Canada during 1899. (Can. Rec. Sci. vol. 8, pp. 232, July, 1900.)

Ami, H. M.

On the occurrence of Whittlesea in Nova Scotia. (Ottawa Naturalist, vol. 14, p. 99, Aug. 1900.)

Ami, H. M.

On the sub-divisions of the Carboniferous system in eastern Canada. (Trans. Nov. Sco. Inst. Sci., vol. 10, pp. 162-178, 1900.)

Barbour, E. H.

Glacial grooves and striæ in southeastern Nebraska. (Jour. Geol., vol. 8, pp. 309-312, May-June, 1900.)

Barrett, R. L.

The Sundal drainage system in Central Norway. (Bull. Am. Geol. Soc., vol. 32, pp. 1-21, 1900.)

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology, and mineralogy.

Beecher, C. E.

Restoration of Stylonurus Lacoanus, a Giant Arthropod of the upper Devonian of the United States. (Am. Jour. Sci., vol. 10, pp. 145-150, Aug. 1900.)

Beede, J. W.

Two new crinoids from the Kansas Carboniferous. (Kans. Univ. Quart. vol. 9, pp. 21-24, 1 pl. Jan. 1900.)

Buchan, J. S.

The rock formation of the Bermudas. (Can. Rec. Sci. vol. 8, p. 219, July, 1900.)

Buckley, E. R.

The properties of building stones, and methods of determining their value. Part II. (Jour. Geol. vol. 8, pp. 333-359, May-June, 1900.)

Daly, R. A.

The lithology of ancient marine sediments. (Science, vol. 12, p. 149, July 27, 1900.)

Davis, W. M.

Glacial erosion in the valley of the Ticino. (Appalachia, vol. 9, pp. 136-156, Mar. 1900.)

Davison, Charles

Methods of studying earthquakes. (Jour. Geol., vol. 8, pp. 301-308, May-June, 1900.)

Dawson, Geo. M.

Descriptive catalogue of a collection of the economic minerals of Canada. (Paris International Exposition, 1900.)

Dresser, J.

Notes on the glaciation of Mt. Oxford. (Can. Rec. Sci., vol. 8, 223. July, 1900.)

Evans, N. N. (and O. E. Leroy.)

On the Height of Orford mountain. (Can. Rec. Sci., vol. 8, p. 225. July, 1900.)

Haworth, E.

Mineral resources of Kansas for 1899, Univ. Geol. Survey. Bulletin, May, 1900, pp. 67. 5 pls. Lawrence, 1900.

Hayes, C. W.

The relation of biology to physiography. (Science, vol. 12, pp. 131-133, July 27, 1900.)

Hoffmann, G. C.

Report of the section of chemistry and mineralogy. (Geol. Sur., Can. Part R, vol., 11 pp. 55, Ottawa, 1900.)

Hillebrand, W. F. (and F. L. Ransome)

On carnotite and associated vanadiferous minerals in western Colorado. (Am. Jour. Sci., Aug. 1900, vol. 10, pp. 120-144.)

Ingall, E. D.

Section of mineral statistics and mines (Canada); annual report for 1898. (Geol. Sur. Can., part S, Amn. Rep., vol. 11, pp. 193, Ottawa, 1900.)

Keyes, C. R.

Coal Floras of the Mississippi valley. (Science, vol. 11, p. 898, June 8, 1900.)

Keyes, C. R.

Kinderhook stratigraphy. (Jour. Geol., vol. 8, pp. 315-321, May-June, 1900.)

Knight, W. C.

New Jurassic vertebrates. (Am. Jour. Sci.. vol. 10, Aug. 1900, pp. 115-119.)

Leroy, O. E. (N. N. Evans and)

On the Height of Orford mountain. (Can. Rec. Sci., vol. 8, p. 225, July, 1900.)

Matthew, G. F.

A forest fire at St. John about 2,000 years ago. (Can. Rec. Sci., vol. 8, p. 213, July, 1900.)

Matthew, G. F.

Oldhamia. (Can. Rec. Sci., vol. 8, p. 228, July, 1900.)

Merrill, Geo. P. (and H. N. Stokes)

A new stony meteorite from Allegan, Michigan, and a new iron meteorite from Mart, Texas. (Proc. Wash. Acad. Sci., vol. 2, pp. 41-68, 6 pls., July 25, 1900.)

Monroe, C. E.

Notice of a new area of Devonian rocks in Wisconsin. (Jour. Geol., vol. 8, pp. 313-314, May-June, 1900.)

Mudge, E. H.

Further notes on preglacial drainage in Michigan. (Am. Jour. Sci., vol. 10, pp. 158-160, Aug. 1900.)

Rogers, A. F.

A new genus and new species of Bryozoans from the Coal Measures of Kansas and Missouri. (Kans. Univ. Quart., vol. 9, pp. 1-12, 4 pls. Jan. 1900.)

Reusch, Hans

A note on the last stage of the ice age in Scandinavia. (Jour. Geol. vol. 8, pp. 326-332, May-June, 1900.)

Sellards, E. H.

Note on the Permian flora of Kansas. (Kans. Univ. Quart., vol. 9, pp. 63-64, Jan. 1900.)

Simpson, C. T.

On the evidence of Unionidae regarding the former courses of the Tennesse and other southern rivers. (Science, vol. 12, pp. 133-136, July 27, 1900.)

Stearns, E. C.

The fossil shells of the Los Angeles tunnel clays. (Science, vol. 12, pp. 247-250, Aug. 17, 1900.)

Stokes, H. N. (Geo. P. Merrill and)

A new stony meteorite from Allegan, Michigan, and a new iron meteorite from Mart, Texas. (Proc. Wash. Acad. Sci., vol. 2, pp. 41-68, 6 pls., July 25, 1900.)

Tarr, R. S.

Glaciation of Mt. Ktaadin, Maine. (Bull. Geol., Soc. Am., vol. 11, pp. 433-448, ph.30-39, June, 1900.)

Van Hise, C. R.

Some principles controlling the deposition of ores. (Trans. Am. Inst. Am. Eng., vol. 30, pp. 151, Wash. Meeting, Feb. 1990.)

Walcott, C. D.

The work of the United States Geological Survey in relation to the mineral resources of the United States. (Trans. Am. Inst. Min. Eng., vol. 30. Wash. Meeting, Feb. 1900,)

Weed, W. H.

The enrichment of gold and silver veins. (Trans. Am. Inst. Min. Eng., Washington meeting, Feb. 1900.)

Weed, W. H.

Enrichment of mineral veins by later metallic sulphids. (Bull. Geol., Soc. Am. vol. 11, pp. 179-206, April, 1900.)

Willis, Bailey,

Work of the United States Geological Survey, 1899-1900. (Science, vol. 12, pp. 241-246, Aug. 17, 1900.)

Williston, S. W.

Some fish teeth from the Kansas Cretaceous. (Kans. Univ. Quart. vol. 9, pp. 27-42, 7 pls., Jan. 1900.)

Winchell, A. N.

Étude minéralogigue et pétrographique des roches gabbroiques de l'État de Minnesota, Etats Unis, et plus spécialement des anorthosites. (Thèse presentée pour obtenir le titre de docteur de l'université de Paris. 162 pp. 9 plates, Paris, July, 1900.)

Woodworth, J. B.

Glacial origin of older Pleistocene in Gay Head cliffs, with note on fossil horse of that region. (Bull. Geol. Soc. Am., vol. 11, pp. 455-460. June, 1900.)

Woodworth, J. B.

Vertebrate footprints on Carboniferous shales of Plainville, Mass, (Bull. Geol. Soc. Am., vol. 11, pp. 449-454, pls. 40-41, June, 1900.)

CORRESPONDENCE.

FURTHER NOTE ON UINTACRINUS. In the August, 1899, number of this journal I announced the discovery of a dicyclic base in certain specimens of Uintacrinus socialis Grinn. Further study of the material in my hands has disclosed the nature of the tegmen of this genus hitherto unknown. It proves to have a disk consisting of an integument or skin, which is black in the fossil state, thickly studded with calcareous spicules of irregular form and arrangement, and not in contact with each other. The center of the disk is occupied by a large anal tube, while the mouth is at the margin, and from it, the ambulacra follow the periphery of the disk, connecting with the several arm branches. Such a form of tegmen has not been known in any crinoid, recent or fossil, except in the living comatulid genus, Actinometra, with which it is in all essential particulars apparently identical. As in that genus, Uintacrinus, has no calcified ambulacral skeleton, either on the disk or arms. I give this preliminary note of the discovery for the information of investigators. A full description of this and other structures of this crinoid will appear in a fully illustrated paper now about to go to press.

East Las Vegas, N. M. FRANK SPRINGER.

PERSONAL AND SCIENTIFIC NEWS.

DR. A. S. EAKLE, INSTRUCTOR IN PETROGRAPHY AT HARVARD UNIVERSITY, has gone to the University of California.

PROFESSOR C. R. VAN HISE AND J. MORGAN CLEMENTS spent July and August in a study of the pre-Cambrian geology of the north shore of lake Superior.

MR. FRANK LEVERETT AND MR. F. B. TAYLOR are engaged on the glacial geology of the southern peninsula of Michigan for the United States Geological Survey, in the region of Saginaw bay and southwestward.

MR. S. WARD LOPER, curator of the Museum of Wesleyan University, has gone to Cape Breton island under the auspices of the U. S. Geological Survey to study the pre-Cambrian geological formations discovered by Dr. F. S. Matthew. (*Science.*)

PROF. HENRY F. OSBORN returned from Europe 6 September. He attended the International Geological Congress, of which he was elected one of the American vice-presidents, and the Exposition, but spent most of his time studying the fossil mammals, especially rhinoceroses in the museums of Paris and London.

DR. JOHN M. CLARKE AND MR. CHARLES SCHUCHERT have recently visited Nova Scotia for an examination of the fossiliferous Silurian rocks of Arisaig, which seem to constitute a unique development of Silurian strata in North America much more akin to the Silurian of Great Britain than to that of the St. Lawrence valley of New York state or the province of Ontario.

AT THE LATE MEETING of the American Association for the Advancement of Science a committee consisting of John M. Clarke, W J McGee, J. McK Cattell, Chas. H. Hitchcock and Theo. Gill, was appointed to report on the erection of a bronze tablet to mark the house in Albany where the geologists of New York in 1838 met to make arrangements for the Association of American Geologists, the parent body of the American Association for the Advancement of Science. (*Science.*)

AT THE SAME MEETING DR, ERASMUS HAWORTH described the recent discovery of native copper in Garfield county, Oklahoma. It is found in the "red beds" of Cretaceous age, in a clayey shale, in the form of thin circular discs about an inch in diameter, which do not lie in concordance with the stratification of the bed, but were introduced by some later chemical reaction from solution.

According to Prof. A. A. Julien, who read a paper on the genesis of pegmatyte in North Carolina, pegmatyte is probably not due to intrusion as dikes, nor to infiltration as veins, nor yet to segregation; it is rather to be considered as an aggregate of the very schist material which encloses it, softened to a plastic condition by thermal or superheated waters and afterwards consolidated with the concretionary structures which it now presents.

Wisconsin Geological and Natural History Survey. The work in geology for the present summer is distributed as follows: Dr. E. R. Buckley is engaged in economic geology, primarily on the clays ot the state. He is assisted by Mr. J. L. Nelson on the marls and by Mr. S. B. Peppel, chemist to the survey, on analyses of the clays. Dr. Samuel Weidman is studying the pre-Cambrian rocks of central Wisconsin. Prof. D. P. Nicholson is preparing a report on the physiography of Vilas and Oneida counties. Prof. U. S. Grant, assisted by H. M. Adkinson and H. F. Little, is at work on the copper-bearing rocks in the northern part of the state. Prof. N. M. Fenneman is investigating the lakes of southern Wisconsin.

The Paleontological Collection of the late Dr. Alexander Winchell was recently purchased for the Hood Museum of Natural History, of Alma College, Michigan. This was done mainly through the instrumentality of state geologist Lane who was desirous to hold the collection in the state of Michigan with the view to make it ultimately useful in the furtherance of the paleontology of the Michigan survey. The collection has had much work put upon it, and, with the drawings of fossil types which are embraced in it, and the descriptions published several years ago by the Philadelphia Academy of Natural History, it carries with it the keys to the most important part of the paleontological work of Dr. Winchell.

The Billings Memorial committee of the Ottawa Field Naturalists' Club is proceeding effectively toward the accomplishment of its purpose. This is to procure some permanent testimonial to the late Mr. E. Billings who was long associated with the Canadian Geological survey as paleontologist, and who as a pioneer did for Canada much of the same service that James Hall did for United States paleontology. Had Mr. Billings lived as long his name would have equally adorned the paleontology of America. A fund is being raised for a portrait to be placed in the Museum of the Geological Survey at Ottawa, and perhaps a memorial tablet on some prominent Canadian rock bluff whose fossils he described. Subscriptions to this fund can be sent to Mr. B. E. Walker, Toronto, or Dr. H. M. Ami, Ottawa.

THE

AMERICAN GEOLOGIST.

VOL. XXVI. OCTOBER, 1900. NO. 4

MINERALOGICAL AND PETROGRAPHIC STUDY OF THE GABBROID ROCKS OF MINNESOTA, AND MORE PARTICULARLY, OF THE PLAGIOCLASYTES.*

(Plate XX.)

[Continued. See other plates in the September Number.]

By ALEXANDER N. WINCHELL, Butte, Mont.

CHAPTER III. Olivine Diabase.

The olivine diabase is entirely similar in method of occurrence to the normal diabase; indeed the intrusive gabbro, like the deepseated gabbro much oftener contains olivine than not. The same columnar structure is every where found in the olivine diabase, which occurs in the same general geographical areas and in the same geological relations as the normal diabase.

The typical sample for this chapter came from the extreme eastern part of the area of gabbros in Minnesota; it is derived in fact, from the extremity of Pigeon point. It probably formed part of one of the numerous "Logan sills," of the north coast of lake Superior, though diabase masses of other origin are said to exist in the region of Pigeon point. The contact area which is also found here presents intense metamorphic phenomena, but the sample studied does not belong to the contact zone.

In color the olivine diabase is a mottled gray always green-

ish; besides the minerals seen in normal diabase green olivine occurs, usually abundantly.

On decomposition the rock becomes darker as the olivine alters to bowlingite, etc., and the pyroxene to hornblende; bitotite often appears also.

Texture—Microscopically the ophitic texture is very prominent (see plate IX, figure 2), and the order of crystallization is:

Accessory { Apatite / Magnetite, Allanite

Essential { Labradorite / Olivine / Pyroxene

Pyrite and ilmenite also occur; they crystallized in general at the same time as the magnetite. Finally traces of vermicular quartz have been found.

The relative time of consolidation of the allanite is not well known; it is rare and has only been found enclosed in pyroxene and secondary minerals; it may therefore be of formation somewhat later than indicated above. The other minerals formed in the order indicated with the usual exceptions due to the fact that one period of crystallization is scarcely ever completed before the next begins. The labradorite seems to have crystallized almost wholly before the pyroxene, but its relation to the olivine is not so well defined. The latter has sometimes a rough outline nearly its own, but oftener it molds itself around sharply defined crystals of feldspar and sometimes it may be found in triangular areas limited by the plagioclase crystals. Thus while in part cotemporary with the latter the olivine is in general slightly later than the labradorite. The pyroxene in exceptional cases seems to be automorphic toward the olivine.

PRIMARY MINERALS. The *feldspar* of the olivine diabase is a labradorite of varying basicity. Twinning is very abundant, and in one thin section a single anhedron shows four types, namely albite, Carlsbad, pericline and Baveno. This is the only case in which the last type of twinning has been found in this rock series. It occurs in a section of normal diabase (954) from Birch lake. (See Plate IX, Fig. 1.) The acute bisectrix

is n_g and the optic angle is large. The maximum equal extinction in the zone perpendicular to $g^1(010)$ exceeds 34°; the extinction in sections perpendicular to n_g varies between 33° and 38°; while in sections perpendicular to n_p it varies from 57° to 59°; the extinction in cleavage pieces parallel to $p(001)$ is usually over 10°, varying to 15°, while parallel to $g^1(010)$ it varies from 23° to 29°. The feldspar therefore varies in composition between $Ab_3\ An_4$ and $Ab_1\ An_2$.

The analysis of this feldspar by Bayley gave the following results:

	I
SiO_2	53.73
Al_2O_3	30.39
Fe_2O_3	1.26
CaO	10.84
Na_2O	3.76*
	100.00
Sp. Gr.	2.699

I. Labradorite from olivine diabase from Pigeon point, Minn. W. S. Bayley. Op. cit., p. 34.

The *pyroxene* of the Pigeon point diabase presents certain very exceptional peculiarities. It shows the ordinary cleavage at 93°, parting parallel to $p(001)$ and more rarely parallel to $h^1(100)$, twinning parallel to the same planes and high refringence. The color is variable, sometimes being absent, and at other times distinct. The absorption formula is not determinable in thin section. In mass the mineral is black; in thin section it is greenish brown with weak pleochroism:

n_g = pale green
n_m = pale yellowish green
n_p = pink (or flesh colored)

Bayley† found that the colorless variety gave a maximum extinction angle in the vertical zone of only 7° 30′, and had a rather low birefringence. In sections of the olivine diabase (1843) a pink pyroxene showing the characteristic cleavage at 93°, and extinction bisecting the cleavage angle in transverse sections, alters quite readily to brown and green horn-

*By difference.

†W. S. Bayley: Op. cit., p. 36.

blende, and also to biotite. The refringence is very high as in all pyroxenes.

The maximum birefringence is very near the normal producing colors as high as a clear green with:

$$n_g - n_m = .022 \text{ to } .020$$
$$n_m - n_p = .001 \text{ to } .003$$
$$n_g - n_p = .023 \text{ to } .023$$

As indicated by these values the angle of the optic axes is extremely small; indeed the hyperbolas of the interference figure scarcely separate, whereas in all known pyroxenes they should, not only promptly separate, but entirely leave the field of the ordinary microscope. So far as known to the writer no pyroxene* has ever been described having an optic angle (2E) less than 65°, and in all the common varieties† this angle is very constant and exceeds 100°. There exists normally a variation of one or two degrees in the value of the angle in common monoclinic pyroxenes, and the studies of Wülfing, Doelter, and others seem to show that the angle in the non-aluminous pyroxenes increases directly with the amount of FeO. In the aluminous pyroxenes the angle varies very slightly and no certain relation has been established. In the sodic augites the angle increases with the amount of iron and sodium.

Thin sections of the olivine diabase (1843) from Pigeon point present the remarkable anomaly of a pyroxene whose angle even in a single section is distinctly variable, and sometimes becomes so small as to be nearly uniaxial. Thus in one section an anhedron directly perpendicular to the bisectrix gives from the measure of *2d* with the axial goniometer of Lacroix, the value‡: 2E=13° 16′. This small angle seems to be nearly constant in the one thin section, but in others from the same rock sample the angle varies from 2E=22° 55′ to 2E=48° 33′ and 2E=49° 3′, while a number of grains from

*Since this was written the writer has been informed that the same anomaly was discovered by Prof. N. H. Winchell about a year ago, while studying rocks from the same locality; see Vol. V, Final Rep. Geol. Nat. Hist. Surv. Minn.

†That is: augite, diopside, diallage, enstatite and hypersthene.

‡Allowing for the maximum of error due to the fact that the hyperbolas are not sharply defined, the section being very thin, the angle 2E certainly does not exceed 15°.

those used for the chemical analysis, mounted in balsam presented one grain nearly oriented, from which the measure of $2d$ gave: $2E=62° 24'$. Thus a whole series of variations exist in this one rock.

$$2E = 13°16'$$
$$2E = 22°55'$$
$$2E = 48°33'$$
$$2E = 49°3'$$
$$2E = 62° 24'$$

To this series might be added two measures from the pyroxene of the gabbro rocks near Duluth, which resulted:

$$2E^* = 56° 33'$$
$$2E\dagger = 67° \text{ about}$$

And it may be added that even higher values very possibly exist, which it has been impossible to measure. At the same time not a single instance has been found in which it was not possible to measure the angle when the section was exactly perpendicular to the bisectrix. It therefore seems probable that a continuous series of values exist from the smallest observed to the normal value ($2E=110°$ about.)

The dispersion is weak with $\rho > v$ about n_g. So far as observed the maximum extinction angle in the vertical zone does not exceed 30°. Distinct twinning occurs rather uncommonly parallel to h^1(100). The mineral often presents a peculiar texture, or rather two textures, which deserve mention. In one case the large areas divide themselves between crossed nicols into a number of irregular areas of slightly, but distinctly different extinction angles. Often, but not always, a very slight difference in color can be detected in the different areas, one being very pale green, and the other colorless, or pale pink. In this texture the cleavages show no perceptible change in direction in passing from one area to another, indicating that crystallographically the whole anhedron belongs to a single crystal, while optically it may be divided into half a dozen areas, undoubtedly of slightly variable composition.

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*See chapter VI, Orthoclase gabbro.

†Measured on a section of a diabase from near Duluth, kindly loaned the writer by Prof. A. Lacroix, of the Muséum d'Histoire Naturelle, Paris.

This texture has been styled "zonary" by Grant*, but in the cases observed by the writer, scarcely any zonal arrangement can be seen, the various areas being apparently wholly irregular in relative position. In the second texture, the same division into areas of different orientation is to be observed, but no difference of color exists. On the other hand, the cleavages change more or less in direction in passing from each area into another. This texture has been called "polysomatic" by Lawson†. The mineral appears as if it had been subjected to severe strain at some time, which has twisted the crystal without breaking it. At the same time the surrounding minerals, which clearly formed before the pyroxene (ophitic texture), show no sign of the least pressure. The explanation which the writer would offer is that after the complete formation of the labradorite crystals, and after the pyroxene had also crystallized, but was, nevertheless, still slightly plastic, the rock suffered a strain insufficient to affect the labradorite, but sufficient to deform the still plastic pyroxene. An example of such a deformed pyroxene is shown in Plate XVII, Fig. 4; it must be repeated that the surrounding feldspar crystals are wholly intact.

The mineral alters commonly to brown hornblende; it sometimes alters directly to biotite; oftener it alters first to hornblende which in turn produces biotite. It also changes to chlorite.

This pyroxene was isolated in the following manner: the minerals of gravity less than 3.31 were first separated out of the powdered rock. A weak bar magnet then removed a part of the magnetite, and afterward a strong electromagnet removed considerable more. The remaining powder was then digested in warm hydrochloric acid for twelve hours, filtered, dried, and again passed through the heavy liquid (3.3), thus removing all trace of olivine. Examined with the microscope it appeared that the pyroxene was wholly unattacked, but there still remained a very appreciable amount of an opaque black mineral having the lustre of magnetite; since it was not attracted by a strong magnet nor soluble in warm hydrochloric

*U. S. Grant: The geology of Kekequabic lake: 21st Ann. Rep. Geol. Nat. Hist. Surv. Minn. 1893.

†A. C. Lawson: Notes on some diabase dikes in the Rainy lake region: Amer. Geol. I, 1888.

acid it must be ilmenite. These grains were mechanically separated out with no difficulty, though the operation is trying to the patience and perseverence of the operator. A qualitative test for titanium confirmed the presence of ilmenite, as it showed much TiO_2 in these grains. A small part of the powder obtained mounted in Canada balsam was sufficient to determine that the same material used for the analysis showed the peculiarly small optic angle.

The material, purified as described, gave the results in the column I; in the second column are the results of the only other analysis known of pyroxene from Pigeon point:

	I	II
SiO_2	45.05	48.34
TiO_2	4.39	1.98
Al_2O_3	.16	2.90
Fe_2O_3	5.50	4.68
FeO	14.90	14.15
MnO	1:58	
MgO	15.15	11.34
CaO	10.72	15.10
Na_2O	1.27	
K_2O	.78	
H_2O	.13	
	99.63	98.49

I. Pyroxene from the olivine diabase (1843) from Pigeon point, Minn.

II. Pink titaniferous diallage from the olivine diabase from Pigeon point, Minn.; partial analysis by Dr. R. B. Riggs. (See Bayley: Bull. 109, U. S. Geol. Survey.)

The specific gravity of the pyroxene is greater than 3.316, but only slightly; grains containing the least alteration or impurity were thereby rendered lighter than 3.316 and thus separated from the rest.

The amount of titanium oxide found is very notable, but so far as known this element has no effect on the optic angle, titanaugite having as large an angle as ordinary augite. The alumina was determined by difference as given, but careful and repeated microchemical tests show no trace of alumina. The manganese gives a good qualititative test, but is not in important amount. The potassium is high as compared with

the sodium found. A test, not very delicate, was made for chromic acid, and a delicate test was made for vanadic acid; both gave negative results. The qualitative test for titanium was, of course, very strong. The pink color is probably in part due to this element.

The analysis then shows that the mineral is a titaniferous diopside, possessing no very marked chemical peculiarities. (See Plate XX, figure 10.) The abnormal optical properties, therefore, can scarcely be attributed to the chemical composition. Though pyroxene is not among the minerals whose optic angle is notably affected by heat, it seems to the writer that the peculiar condition here described must be ascribed to peculiar physical conditions during or after the crystallization. Since the anomalous condition was first discovered in the rocks from Pigeon point, it would be appropriate to call pyroxene thus optically abnormal *pigeonite*.

The mineral has been found also in two gabbroid rocks from near Duluth, at the other extremity of the same great gabbro area.

Olivine is usually abundant. It sometimes forms rounded automorphic crystals, but is often penetrated by the labradorite crystals. The cleavages are occasionally very distinct when alteration has set in; oftener they are entirely lacking.

The birefringence gives very clear colors rising often into the second order; it is at least .034.

In the process of separating the pyroxene from this rock, the coarse powder containing pyroxene, olivine, and a little highly titaniferous and wholly non-magnetic ilmenite was digested in hydrochloric acid at a gentle heat for several hours. An examination with the microscope showed that the ilmenite and the pyroxene were not perceptibly attacked. From the solution thus obtained the iron and magnesia were precipitated:

$$FeO = .0522 \text{ mg.}$$
$$MgO = .0534 \text{ mg.}$$

From this the theoretical composition of the olivine would be:

$$SiO_2 = 33.57$$
$$FeO = 48.74$$
$$MgO = 17.69$$

The ratio of Fe to Mg is thetrefore very nearly 5:4, and the mineral is accordingly an "hyalosiderite" remarkably rich in iron. Qualitative tests show such slight traces of TiO_2 that this result may be considered sufficiently exact since the proportion of ilmenite attacked must have been extremely small.

Magnetite varies much in abundance; it is usually titaniferous as shown by the leucoxene found by Bayley, and the titanite, well crystallized, and highly birefringent found by the writer. Octahedral parting occurs uncommonly. Decomposition similar to that observed in the plagioclasyte occurs as well as the alteration to titanite. The first change is to an amorphous dull black substance, not at all metallic in lustre; this is probably amorphous magnetite; to this succeeds, in the Birch lake diabase, well crystallized pyrite with very characteristic brass-yellow reflection. Mesogenesis of biotite between the magnetite and feldspar is quite common.

Magnetite is occasionally automorphic, but it is oftener of very irregular shape; it is often enclosed by the pyroxene and feldspar, and nearly as often occurs in irregular masses filling the interstices. A peculiar pegmatitic intergrowth of magnetite and augite occurs in the olivine gabbro from Birch lake. (See Plate VII, Fig. 2.)

An opaque black mineral which seems to give the blue-black metallic lustre of magnetite occurs in the olivine diabase from Pigeon point as a minute inclusion of irregular outline in clinochlore in which it causes a very marked pleochroic halo, which is peculiar in showing a lighter circle inside the darker one. (See Plate XVII, Fig. 5.) The refringence and, apparently, the birefringence are increased by the halo.

Apatite is the only other original mineral reported by Bayley; it occurs in the usual colorless acicular crystals with hexagonal cross sections. It is strictly uniaxial and negative with parallel extinction and negative elongation. The birefringence is very weak (.004). Very minute dust-like inclusions, probably magnetite, are often abundant. These are sometimes arranged along curving planes. Liquid inclusions are uncommon; they sometimes contain one or more particles of magnetite(?). Apatite often causes marked halos in brown and green hornblende and in biotite.

Allanite occurs in minute crystals, often rounded, or even

irregular in outline. Good crystal outline has not been seen in the mineral of the Pigeon point rock; in the gabbro from Birch lake the faces m (110) and h^1 (100) form a complete outline in one case. (See Plate XVII, Fig. 6.)

The color and pleochroism are intense and characteristic with:

n_g	=	pale brown slightly greenish	greenish brown
n_m	=	dark brown to opaque	dark greenish brown
n_p	=	dark yellow brown	greenish yellow

The absorption is strong: $n_g > n_p > n_m$.

The cleavages are indistinct or wanting; irregular coarse fractures exist frequently. The refringence is very high, exceeding that of all the minerals seen surrounding it, namely biotite, brown and green hornblende and augite. The birefringence is extremely variable and may vary even in a single crystal; it has been observed as low as .007, in which case the mineral is of a paler brown or green color and only feebly pleochroic. In other cases the birefringence reaches .027 at least, in which case the color and pleochroism are so intense as to nearly mask the birefringence. The dispersion is usually strong and prevents complete extinction. The extinction is sensibly parallel to the elongation, usually very slight, which is positive or negative.

Allanite produces very intense pleochroic halos in all the colored minerals in which it has been observed; these halos sometimes have a diameter more than twice as long as the diameter of the included allanite. In brown biotite it causes intense greenish brown halos strongly pleochroic; in brown and green hornblende it causes intense brown halos, strongly pleochroic to pale yellow. The refringence is distinctly increased in these halos and in one case the birefringence is increased at least .003. This is in green hornblende. The halo is usually only approximately circular; one peculiar double halo in brown hornblende consists of two rings exactly circular, the outer one being very much lighter; both are very clearly defined. (See Plate XVII, Fig. 7.)

Pyrite occurs rarely and sparingly as a primary constituent. Its time of crystallization was long or varied. Indeed it sometimes occurs in automorphic forms enclosed by augite or labradorite, and at other times it is wholly irregular in outline

and crystallized between other minerals. The brass-yellow color with strong metallic lustre in reflected light is very characteristic. The refringence is higher than that of augite. Alteration to limonite has not been observed in the diabases, but pyrite seems frequently to furnish iron for the formation of biotite and clinochlore.

Ilmenite seems to occur in small quantity accompanying the much more prevalent magnetite.

Finally vermicular *quartz* has been found in small quantity, and in one case primary quartz seems to occur in anhedral form.

Inclusions. The labradorite (as well as the other minerals) is usually quite fresh and its inclusions can be studied to advantage. It nearly always contains the minute black dust-like inclusions which have already been described as occurring in the normal gabbro; they are usually less abundant or altogether wanting about masses and grains of magnetite. The black acicular inclusions so often found in gabbros are often present in their usual form, and are sometimes very abundant. The ilmenitic colored microplakites and microphyllites have not been found in the diabases. The opaque black needles are nearly always markedly lacking about grains and masses of magnetite, as if the latter had in crystallizing drawn to and incorporated in themselves the elements which elsewhere form these inclusions. Therefore the needles are considered to be of the same composition as the masses. To determine the nature of the latter the heavy minerals were separated out of the rock powder with tetrabromide of acetylene; from these heavy minerals the black metallic mineral was separated out by careful mechanical selection, grain by grain; finally these grains were carefully examined with the microscope, and every one containing any foreign element was separated out. The weight of absolutely pure mineral thus obtained was .002 gr. This amount was fused with potassium bisulphate, and the fused mass was tested by putting a bit in a few drops of sulphuric acid to which had been added about .0005 gr. of morphine. A similar test was made using hydroquinone instead of morphine. Both methods* gave remarkably good tests for titanic acid. Re-

*The methods followed give the color reactions proposed by L. Lévy: Sur quelques réactions colorées des acides titanique, niobique, tantalique, et stannique. C. Rendus, CIII, 1886.

membering how small an amount of original mineral was employed the per cent of titanic acid must be considerable. Nevertheless the mineral is not ilmenite or, at least, is not always ilmenite, since it occasionally shows good octahedral parting and is strongly attracted by a rather weak bar magnet. The mineral is, therefore, in large part at least, magnetite, rather highly titaniferous, and it is probable that the acicular inclusions are also titaniferous magnetite.

Liquid inclusions are not common in the material studied, though they occur sparsely scattered throughout the feldspar.

The pyroxene very often shows the fine closely set parting lines, parallel to h^1(100), characteristic of diallage. It is along these lines that the inclusions are most abundant, though they are often placed at right angles to the parting direction, and may occur when the parting is absent or only very poorly developed. They also occur scattered haphazard throughout the pyroxene, then having no definite orientation. These are the inclusions characteristic of bronzite, but scarcely less common in diallage and hypersthene. They occur as lamellæ usually lying in the plane h^1 (100); in sections perpendicular to this plane (e. g. in sections perpendicular to g^1(010) and h^1(100), and in sections parallel to g^1(010), they are cut at right angles and show a narrow straight edge, looking like acicular inclusions. In sections more or less nearly parallel to h^1(010), on the other hand, they show their lamellar character; the lamellæ, however are decidedly elongated in a direction perpendicular to h^1g^1(100)(010), and the vertical axis. Their outlines as seen in sections nearly parallel to h^1(100) are very irregular, showing none of the ordinary rectangular appearance.

Besides these inclusions, opaque, black needles occur, usually parallel with p(001), which seem identical with those found in the labradorite and are therefore considered to be titaniferous magnetite. In some cases they are apparently secondary. No other inclusions have been noted in the pyroxene.

Original inclusions in olivine seem to be very rare; a few liquid inclusions have been noted, and certain magnetite crystals are apparently primary inclusions.

The apatite occasionally contains fine grains of a black,

opaque mineral, probably magnetite; it is quite possible that these are of secondary origin; liquid inclusions have also been observed, but not commonly.

The *alterations* of the olivine diabase have been described by Bayley*; the results of this alteration are the same as those produced by the alteration of the normal gabbro with the exception of pectolite and the addition of titanite. These minerals are the following:

Calcite.	Hematite.
Muscovite (?)	Pyrite.
Penninite.	Bowlingite.
Clinochlore.	Antigorite.
Hornblende.	Titanite.
Magnetite.	Biotite.

SECONDARY MINERALS. *Calcite* presents no unusual features; it forms at the expense of labradorite by endogenesis. It is easily recognized by its extreme birefringence and its uniaxial negative character.

Muscovite is exceedingly difficult to distinguish under the microscope from certain other minerals, especially paragonite, margarite, pyrophyllite and talc. The measure of the optic angle will usually distinguish it from all except paragonite: but this measure is often impossible, especially when the mineral occurs, as in the diabases, in the form of microscopic scales much too small to give a satisfactory interference figure. Nevertheless it is probable that the mineral is a muscovite (perhaps damourite) since it is a matter of frequent observation that the result of the process of sericitization, is nearly always muscovite even in the basic rocks, where the process is comparatively rare, probably from lack of potassium.

The mineral under discussion is eminently lamellar in habit, and shows a perfect cleavage parallel to the faces of the lamellæ. It is transparent and colorless. The refringence is always superior to that of the labradorite. The birefringence is very strong since the thin scales show colors as high as green of the second order. The elongation of the lamellæ is always positive, with extinction sensibly parallel.

*W. S. Bayley: Eruptive and sedimentary rocks on Pigeon point, Minn., and their contact phenomena. U. S. Geol. Surv. Bull. No. 109, 1893.

The mineral occurs as an endogenetic decomposition product of labradorite.

Penninite is lamellar in habit, with perfect cleavage. The color is pale green with a weak pleochroism as follows:

n_g = pale green
n_m = pale green
n_p = pale yellowish green to colorless

Absorption $n_g = n_m < n_p$.

The refringence is somewhat higher than that of labradorite, the birefringence is very weak, and often scarcely perceptible. Penninite is biaxial and negative in the section examined, but the optic angle is very nearly 0°. The dispersion is strong, giving the "ultra blue" and pale yellow colors on either side of the position of the extinction, which is not complete.

The penninite of Pigeon point often contains pleochroic halos. It is an alteration product, both endogenetic, and exogenetic, from labradorite; and is often formed by exogenesis from biotite, hornblende, and augite.

Clinochlore is very similar to the preceding; it differs from it in possessing a notable birefringence, at least .010. It possesses the same color and pleochroism, but with:

n_g = pale yellowish green to colorless
n_m = pale green
n_p = pale green

Absorption: $n_g < n_m < n_p$.

The clinochlore, in sections from Pigeon point, is positive, with a variable, but rather small optic angle. The dispersion is not noticeable. The elongation is negative, with extinction sensibly parallel. In a section from Pigeon point, clinochlore shows marked pleochroic halos, in one case about magnetite. (See Plate XVII, Fig. 5.)

Hornblende is a common product of the alteration of the pyroxene. It is usually compact, and scarcely ever passes through the fibrous condition before altering to chlorite or biotite. It shows good prismatic cleavage at an angle of about 124°; twinning is rare. The color is either brown or more

rarely green, but either one may apparently be formed directly from the pyroxene. The pleochroism is very marked with:

	Halo about allanite.	
n_g = dark brown	dark brown	bottle green (bluish)
n_m = brown	dark brown	pale yellowish green
n_p = brownish yellow	pale yellow	pale yellow

Absorption $n_g > n_m > n_p$.

These colors often mingle as the brown hornblende passes into the green.

The birefringence is strong, being .030, at least, in the brown hornblende and somewhat less in the green hornblende. The extinction angle in sections of the vertical zone varies from 0° to at least 17°.

Hornblende often contains pleochroic halos about inclusions of apatite, allanite, etc. These halos are usually of a greenish brown color, and thus the brown color is conspicuous in green hornblende, while the greenish tint is very evident in brown hornblende.

Hornblende has been observed in small patches surrounded by labradorite, but it is believed to be secondary here also, though it is not fibrous.

Magnetite and *pyrite* occur as secondary as well as primary minerals; the latter sometimes being derived from the former.

Hematite is decidedly uncommon; its blood red color prevents its being overlooked.

Bowlingite is the commoner decomposition product of the olivine and is always present. It has a lamellar cleavage parallel to h^1(100), and perpendicular to the optic plane. The color of bowlingite is variable, probably according to the state of oxidation of the iron, from green to brown; it is always pleochroic with:

n_g =	green	greenish brown	dark brown	dark reddish brown
n_m =	yellowish green	brown	brown	reddish brown
n_p =	pale greenish yellow	light greenish yellow	yellowish brown	reddish yellow

The absorption is always $n_g > n_m > n_p$.

The pleochroism is very variable in intensity, and even indistinguishable when the mineral is only feebly birefringent.

The birefringence is quite variable according to the degree of crystallinity of the mineral; the maximum, however, is at least .025.

All conditions of crystallinity occur in bowlingite, from the compact perfectly crystallized state through lamellar and fibrous varieties to the earthy noncrystalline condition. The last evidence of crystalline character to disappear is the birefringence, which though feeble can be distinguished when all other evidences of crystallization have disappeared.

The alteration of olivine to bowlingite begins along the edges of the fractures so characteristic of the former, and spreads inwards. It is thus exogenetic. One crystal may alter to a single crystal of bowlingite, or it may alter to a fibrous mass of varying orientation, or the two conditions may be combined. In the first case the bowlingite is oriented on the olivine so that the optic planes are mutually perpendicular and n_p of olivine is parallel to n_m of the bowlingite.

Antigorite is the mineral of which "serpentine" is ordinarily composed; but in the Minnesota rocks it is much less abundant than bowlingite, which seems to be a ferriferous mineral of the same group. Antigorite is fibrous or lamellar in habit, never compact. It often presents a rudely radial arrangement of the fibers, and occurs more frequently at some distance from the olivine grains than in them. On altering the olivine increases in volume and hence its decomposition products are forced into the fractures of the surrounding minerals, especially the labradorite. The bowlingite, however, never forms at any distance from the olivine; the microscopic veins running from one olivine grain to another are always composed of antigorite. If an amygdule or cavity of any kind occurs it is filled with antigorite; the fraetures along which the material has been brought are very distinct; they also are filled with antigorite. This is illustrated in plate VIII, Fig. 1.

Titanite occurs in the Pigeon point olivine diabase. It has apparently formed from magnetite, though the two minerals are now slightly separated. It has a pale yellow color without determinable pleochroism. It occurs in brown biotite causing an intense pleochroic halo.

Biotite is formed by mesogenesis between the magnetite

and labradorite, and also by exogenesis of pyroxene, hornblende, and occasionally olivine. It occurs both brown and green, and both varieties are intensely pleochroic, with:

n_g =	brown	reddish brown	green	green
n_m =	brown	reddish brown	grass green	green slightly brownish
n_p =	pale yellow	very pale yellow	brownish yellow	pale green to colorless

The absorption is usually $n_m > n_g > n_p$, but occasionally it is sensibly $n_g = n_m > n_p$. In the normal diabase (954) the optic angle in biotite is unusually large; from the measure of $2d$, $2E = 26°$ about. Both green and brown biotite seem to form directly from the augite; both contain pleochroic halos about apatite, allanite and titanite.

The *chemical composition* is given in the first column following. It contains a little less iron and somewhat more magnesia than the normal diabase. The titanium is doubtless, in part at least, contained in the magnetite.

	I	II
SiO_2	49.18	49.88
TiO_2	1.09	1.19
Al_2O_3	19.01	18.55
Fe_2O_3	.89	2.06
FeO	7.79	8.37
MnO	.51	.09
MgO	6.42	5.77
CaO	9.12	9.70
Na_2O	3.32	2.59
K_2O	.82	.68
H_2O	2.06	1.04
	100.21	100.21
Specific gravity	2.84	2.92 2.97

I. Olivine diabase from Pigeon point, Minnesota (1843). No appreciable BaO nor SrO; P_2O_5 not determined. By W. F. Hillebrand; published by W. S. Bayley: op. cit., p. 37.

II. Olivine diabase from Pigeon point, Minn. Includes BaO=.02 and P_2O_5=.16. By F. W. Hillebrand. Ibid.

Chapter IV. Plagioclasyte.

The term "plagioclasyte" recently proposed by the French Commission on rock nomenclature, is intended to supplant the older name "anorthosyte" which has been the cause of so much confusion in petrographic literature. The latter term has obtained much currency in American geological literature especially through the writings of Hunt, Adams, Lawson, and Coleman, but it is open to serious objection, since it has been confused not only with anorthite, but also with anorthoclase.*

Plagioclasytes, which occur not only in large masses in Minnesota, but also in Canada, New York, Norway, Finland and other countries, constitute a petrographic type of distinct individuality, not a local freak of nature, but a normal rock type, which is found in unvarying composition, in mountain masses, and in widely separated areas.

The plagioclasytes of Minnesota have received various names from the geologists who have made them a study. J. G. Norwood† was probably the first to definitely identify them, and he simply termed them "feldspar rocks." Hunt,‡ studying the same rock in Canada a few years later, called it "labradorite rock" from its composition, or "noryte," since it was supposed to be the equivalent of the original noryte from Esmark, Norway. At the same time he proposed to call the formation "Norian," from his new name of the rock largely composing it, since he considered it of sedimentary origin. Irving,§ from very questionable determinations of the feldspar, called it "anorthite rock." Finally Lawson‖ suggested the term "Carltonian" to designate the plagioclasytes as a formation, which he separated¶ sharply from the other gabbros of northeastern Minnesota.

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*In the French language the triclinic soda-potash feldspar is called "anorthose," with which the rock name is inevitably often confused.

†Report of a Geological Survey of Wisconsin, Iowa, and Minnesota: D. D. Owen. Philadelphia, 1852, p. 380.

‡Amer. Jour. Sci., Nov. 1869.

§R. D. Irving, Geology of Wisconsin, III, 1880.

‖A. C. Lawson: Anorthosytes of the Minnesota Coast of Lake Superior, Geol. Nat. Hist. Surv. Minn. Bull. No. 8, p. 23.

¶Winchell, Van Hise, and Elftman have shown that the separation cannot be maintained; the rocks grade insensibly one into the other.

Adams and others have used the term anorthosyte in a very wide sense, making it nearly synonymous with gabbro, noryte, or even diabase, in different cases. Thus Adams says:* "Beide (i. e., coarse and fine anorthosyte along the Shipsaw river, Canada), zeigen sehr deutlich eine ophitische oder Diabase Structur," etc.

In this article the word plagioclasyte is used in a more restricted sense, so as to be no longer an equivalent of gabbro, but merely a variety of the latter just as lherzolyte is a variety of peridotyte. Thus plagioclasyte is a member of the family of gabbro rocks and is related to typical gabbro in just the same way as pyroxenyte.† That is by a gradual decrease of one of the essential constituents (feldspar) gabbro finally becomes pyroxenyte, while by a similar gradual decrease of the other essential constituent (pyroxene) gabbro passes into plagioclasyte. Plagioclasyte thus stands at one end of the series of gabbro modifications and pyroxenyte at the other. A mixture of plagioclasyte and pyroxenyte in about equal proportions would produce a typical gabbro. The analogue of plagioclasyte in the potassic feldspar series has been called sanidinyte.

OCCURENCE. In Minnesota, typical plagioclasyte occurs at several points along the southern edge of the great gabbro area, as well as further north at Bellissima lake, Little Saganaga lake, and elsewhere. Along the coast of lake Superior (i. e. along the southern edge of the gabbro mass), plagioclasyte has been reported‡ from ten localities, the most important being; near Encampment island,§ Split-rock point, Beaver bay, Baptism river and at Carlton peak. It is from this last locality, where typical plagioclasyte is said to form the whole upper part of a hill three hundred yards high, that the material for this study has been obtained. Typical plagioclasyte is known

*Ueber das Norian oder Ober-Laurentian von Canada. F. D. Adams: Neues Jahrb. f. Mineral. etc. Bd. VIII, p. 451. Cf. also: Report on the geology of a portion of the Laurentian area: Geol. Surv. Canada Ann. Rep. 1896. Vol. VIII.

†A name first proposed by T. S. Hunt for the pyroxenic masses occurring in the great gabbro areas of Canada, but now generally used in the sense proposed by Geo. H. Williams to designate a granitoid rock composed essentially of pyroxene, with no olivine, nor feldspar. See Amer. Geol., July, 1890, p. 47.

‡A. C. Lawson: Anorthosytes of Minnesota Coast of Lake Superior: Geol. Nat. Hist. Surv. Minn. Bull. No. 8, 1893.

§See the map.

nowhere outside of the gabbro area in Minnesota; but it occurs along the northern border of the state in the Rainy Lake region on the Canadian side of the boundary line.

In many other gabbro areas in Canada the predominant rock is plagioclasyte. Thus it occurs in what has been termed the "Morin" area to the north of Montreal, in the Lakefield area, about St. Jerome, in the township of Kildare, on the east side of the township of Cathcart, near the pont des Dalles, near the village of St. Jean de Matha, in the township of Brandon; a very large area occurs about the head waters of the river Saguenay, which may be connected with the area about the head waters of the Moisie river. It is found at several points along the coast of Labrador, notably at Paul island. Two important plagioclasyte areas occur in New York and northern New Jersey. Outside of America, plagioclasytes are known to occur in large areas in Norway, where they have been termed labrador-rock or gabbro. They are known in several localities in the Archean regions of Russia, namely, near Kamenoi-Brod, in the Government of Kiew, in the Government of Cherson, near St. Petersburg, etc. Finally they are reported from Egypt, where they were used in the earliest historic times as material for statues and monuments.

Exterior Characters. The plagioclasyte of Minnesota is remarkable for its freshness; it compares very favorably in this respect with the plagioclasytes from southern Canada, Labrador and Russia. The feldspar is frequently in large granular crystals, which give bright, glassy cleavage faces on which the twinning is usually very plain. The dull earthen appearance of decomposed feldspar is never seen except in the rock at the surface, which has suffered alteration from atmospheric agencies. This form of alteration is common, but it is nearly the only decomposition which the rock has undergone, and it is never more than superficial. The color of the weathered feldspar is a dull white, sometimes greenish, but often also with a reddish tinge, due to the hematite, which is deposited along cleavage lines and curving fracture planes by percolating waters. This is the condition of the rock superficially at Carlton peak. The fresh unaltered rock does not present the play of colors seen on the well known labradorite

from the coast of Labrador: or, at least, the play of colors is rare and indistinct. It is of a prevailingly gray color, varying from light gray to dark greenish gray. In its purest state, which is not uncommon, it is clear and glassy, and transparent even in masses four to five centimeters thick. The remarks of Prof. A. C. Lawson, on the structure as seen in the field, during the summer of 1893, follow:*

"Another remarkable characteristic of the rock as a formation is its massiveness and lack of structural planes of any kind, except under some abnormal circumstances. Even jointage may be said to be entirely absent. Occasionally the formation is traversed by one or more fissures locally, but these follow no law of direction and cannot be regarded as true jointage. There are few of the massive rocks of the lake Superior region so free from structural planes. There is no flow or gneissic structure, and the rock seems nowhere to have been subjected to forces which would tend to deform the mass, render it schistose, or in any way induce the development of secondary structures of a mechanical nature."

At the first glance the rock often presents the appearance of being composed of a single mineral, a feldspar with fine cleavage often showing very distinctly the albite twinning striations. But a closer view will disclose the presence of small grains of dull greenish black augite, distributed rather evenly through the rock; usually filling the interstices between the feldspar crystals, and but rarely possessing any crystal faces. Besides these two minerals a third is nearly always present, in the shape of a bright, black mineral with metallic blue-black reflections. It is magnetite.

When the rock is weathered and decomposition has set in, it is common to see hematite appear and the rock take on a reddish tinge, but at the same time the feldspar alters along its cleavages, which thus become quite conspicuous, and the division into lamellæ gives a dull white appearance to the mass. This color is also due to the fact that the feldspar is altering to various white minerals and especially to zeolites. Indeed, whenever amygdules are found, they are filled with radial masses of these minerals, which are often tinted very

*A. C. Lawson: The anorthosytes of the Minnesota coast of lake Superior: Bull. No. 8, Geol. & Nat. Hist. Surv. Minn. 1893, p. 3.

beautifully varying in regular bands, perpendicular to the fibres, from porcelain white to bright pink, and less commonly to clear green either pale or dark. These amygdaloidal zeolites, while composed of minerals of little hardness, are usually so interlaced as to form the most durable part of the rock, and many may be gathered on the beach of lake Superior, all derived from the disintegration of plagioclasytes and similar gabbro rocks. The finest of these pebbles have found a ready sale among the jewelers of the region, who use them for various decorative purposes.

The TEXTURE of the plagioclasyte is always granitoid and holocrystalline. It varies from very coarse to medium grain, but is generally coarse. Cleavage faces of the constituent feldspar frequently measure one to two centimeters and may even attain four or five. The feldspar is never porphyritic nor ophitic, though occasionally the accompanying rare augite shows a tendency to automorphic forms.

In thin sections the coarseness of the rock is at once apparent for it is not rare that one or two grains of feldspar occupy the whole of a section. At the same time its great predominance is evident, as the augite only occurs as rather small crystals surrounded by, and of earlier growth than, the feldspar, except in the rarer cases when it occurs here and there in small rudely triangular areas, or in narrow lines between the large plagioclase crystals. Indeed it may be stated in general that in Minnesota plagioclasytes a triclinic feldspar of the labradorite series makes up from three-fourths to nine-tenths of the rock. Samples can be found exclusively composed of feldspar, though it is rare that more or less magnetite does not occur. However, the normal plagioclasyte contains also more or less augite, and thus passes by insensible gradations into an ordinary normal gabbro. Apatite also is rarely absent, though it often occurs as only one or two small crystals. Olivine very rarely occurs in ordinary plagioclasyte. Irving claims to have seen "a few grains." Thus the only primary minerals observed are:

Apatite.
Magnetite.
Augite.
Labradorite.

In general the order of crystallization is that given above, but it is probable that the apatite and magnetite crystallized out of the molten mass at about the same time; they are in such small quantity that in crystallizing they never mutually interfered, and consequently the earlier one cannot be determined. Magnetite is occasionally seen enclosed by apatite but in such cases the iron ore is apparently always secondary and due to percolating waters. Both are, however, very distinctly earlier than the great masses of the augite and labradorite. The relation between the magnetite and augite is rarely evident as both are in small quantity, but in one case an augite crystal molds itself about the corner of a well-formed magnetite crystal, and is itself surrounded by xenomorphic feldspar.

In another case, which will be described in detail later, it is clear that the periods of crystallization of the magnetite and augite were partially contemporaneous. The relation between the augite and labradorite is somewhat variable, but in general the pyroxene is of earlier growth; while the larger part crystallized before the feldspar, there remained a very noticeable amount which did not solidify until the crystallization of the feldspar was already well advanced. This part is seen filling in the spaces between the labradorite anhedra. But it must be understood that these spaces are comparatively rare, and that in general the feldspar anhedra are limited only by other crystallizations of the same mineral. Thus the feldspar considered alone forms a mass of very coarse granitic texture. A peculiar and exceptional development of augite (shown in plateX, Fig. 1,) occurs in a section from Carlton peak. It is unfortunately in a highly altered area, so that the augite is nearly separated from the feldspar, and their relations are uncertain. However, it is very probable that the augite is wholly younger than the feldspar. A rather large mass of augite of irregular shape showing a twinning band with composition plane h^1 (100), is surrounded by several small well developed crystals of augite oriented exactly with the contiguous parts of the large mass. Thus the crystals bordering on the twinning band are oriented with it, while the others are oriented with the principal mass. The central mass is surrounded nearly everywhere by a narrow band of magnetite which crystallized before the formation of the satellites. On the other hand the satellites themselves

are completely surrounded by rims of magnetite which are certainly of later date, probably in part secondary. A large mass of magnetite with clearly defined crystal outlines serves to explain the occurrence. At a certain stage of its growth the crystallization of the augite crystal was seriously interferred with by a crystallization of iron oxide over its surface. This prevented the central mass from perfecting its form and showing good crystal faces, but did not prevent it from controlling the orientation of other pyroxene elements as they crystallized. It is interesting in this connection to note that the magnetite rims are noticeably thicker on the side of the augite farther from the large magnetite crystal, as if the iron were intercepted on its way to that crystal; indeed on the small crystals of augite next to the magnetite the rims are very narrow or entirely lacking. This augite area is also interesting since it shows quite clearly the decomposition of the pyroxene, first by the appearance of the diallagic parting and then by transformation to clinochlore, usually with accompanying secondary magnetite. At the same time it shows bands of secondary hematite which follow no law of direction, but propagate themselves irregularly through the pyroxene in a manner very similar to the serpentinization of olivine.

PRIMARY MINERALS.

The primary minerals of the plagioclasyte are: labradorite, augite, magnetite and apatite. These will be passed in review, giving all the characters of each which it has been possible to determine with the material at hand.

The LABRADORITE is by far the most important mineral of the rock, making up as it does frequently more than ninety per cent of the whole. As is well known it takes its name from the peninsula of Labrador on whose coast it was first found by Wolff about the year 1770. It would be useless to enumerate the various names which it has received, such as labradorstein, kalkoligoklas, mornite, silicite, radauite, chatoyant or opaline feldspar, etc.; but it may serve a purpose to show clearly the varying use of the name according to the authorities who have made a special study of the feldspars during the last few years.

It is to Tschermak that we owe the theory of an isomorphous series comprising all the plagioclase feldspars from al-

bite to anorthite. Fouqué, in a detailed study especially devoted to the optic properties of the feldspars of the volcanic rocks, furnished much very valuable data which Michel Lévy has used in support of the theory. Fouqué reached the conclusion that a continuous series does not exist between albite and anorthite; on the contrary a certain number of well defined types exist which are capable of forming physical combinations. In other words labrador-bytownite of Michel Lévy (Ab_2An_3) is not an isomorphous mixture of albite and anorthite, but of labrador-bytownite of Fouqué (Ab_3An_4) and bytownite, which latter however, are not mixtures, but independent types, "forming with the other plagioclases a natural family comparable to the series so well established of organic chemistry." In such series it is still true that all the characters of the intermediate compounds are exactly determined if those of the two extremes be fully known. Thus the theory leads to precisely the same practical conclusions as the theory of Tschermak, differing from the latter mainly in assigning to certain intermediate compounds the same rank as pertain to the extremes. It is a theory based chiefly upon the frequency of certain types, and is very hard to attack, whether one accept it or not. Michel Lévy has shown that slight variations seem to exist uncalled for by a strict interpretation of the theory of Tschermak, but he reached the conclusion nevertheless, that the best results which have been obtained showed an agreement quite satisfactory, and that if the theory is not mathematically exact, it is as near it as any ordinary physical law. In any case, whether one accept the theory of a continuous series between albite and anorthite, or, on the contrary, admit the existence of a limited number of types intermediate between the two end terms, it is necessary for convenience of petrographic description to establish divisions in the series.

These divisions as adopted by different writers are given in the following table, as far as they concern the minerals under discussion. It is necessary to remark at once that if one accept the theory of Tschermak the composition of all the intermediate compounds can be very conveniently represented by the formula, $Ab_n An_m$; this serves in any case as a very simple standard of reference.

	Oxygen ratio 1:3:x	Theoretical Composition SiO_2	Al_2O_3	CaO	Na_2O	Sp. Gr.	Nomenclature of Tschermak*	Schuster†	Fouqué‡	Michel Levy§
Ab_4An_3	7.2	57.4	27.1	8.9	6.6	2.684	Andesine	Andesine	Andesine	And'ne
Ab_1An_1	6.7	55.6	28.3	10.4	5.7	2.694			Labrador	Lab'r
Ab_3An_4	6.2	53.7	29.6	11.8	4.9	2.703			Lab.-Byt.	Lb.bas.
Ab_2An_3	6.0	53.0	30.1	12.3	4.6	2.708	Labrad.	Labrad.		Lb.Byt.
Ab_1An_2	5.6	51.1	31.2	13.7	3.8	2.716				
Ab_1An_3	5.2	49.3	32.6	15.3	2.8	2.728			Bytown.	
Ab_1An_4	4.9	48.0	33.4	16.3	2.3	2.735	Bytown.	Bytown.		

It will be seen at once that the differences of usage are very marked. Take for example labrador-bytownite; according to Michel Lévy it has the composition Ab_2An_3; according to Fouqué it is Ab_3An_4, while Schuster and Tschermak do not recognize it as a subspecies, but if they did would probably consider it respectively $Ab_1 An_2$ and $Ab_1 An_3$. Further, Tschermak and Schuster place the divisions at points whose composition is easily expressed, such as $Ab_1 An_1$ and $Ab_1 An_3$, while Michel Lévy, following a method which seems more practical, prefers to give names to these points, and place the divisions between them. Thus the labradorite of Michel Lévy is neither distinctly a labradorite, nor an andesine, but is at the limit between them according to Tschermak. Fouqué considers $Ab_1 An_3$ a bytownite, since it is with this feldspar that the attack by acids becomes easy; such a marked difference should certainly receive recognition.

For the sake of brevity, the plagioclase of the composition expressed by $Ab_3 An_4$ will be called labradorite throughout this article. It is therefore the same as the labrador-bytownite of Fouqué, and the basic labradorite of Michel Lévy. According to many published analyses as well as according to the optic and crystallographic characters as determined by the writer, it is much the commonest feldspar of the plagioclasytes

*G. Tschermak: Lehrbuch der Mineralogie: Fourth Ed., Wien. 1894, p. 473. Theory first proposed: Sitzb. K. K. Akad. Wissensch. Wien. Dec. 1864. Vol. L., p. 582.

†Max Schuster: Ueber die optische Orientirung der Plagioklase: Mineral. und Petrogr. Mitt. Tschermak: Second series. III, 1880, p. 153.

‡F. Fouqué: L'Etude des feldspaths des roches volcaniques: Bull. Soc. Fr. Min. XVII, 1894.

§A. Michel Lévy: Etude sur la détermination des feldspaths: Paris: 1894, p. 26-7. Idem. Deuxième fascicule: Paris, 1896, p. 107.

and related gabbros in Minnesota, Canada, Newfoundland, New York, Finland, and Russia.

Physical Characters of Labradorite. The albite twinning is very common and shows itself megascopically as a series of striations, usually very fine, on the cleavage face *p*(001). Anhedra showing no twinning are decidedly rare. It is easily seen, even without the microscope, that this twinning has its composition plane parallel to g^1(010) and its twinning axis perpendicular to this plane. It has been noted that one set of twinning lamellæ is much narrower than the other; the finer lamellæ may, however, become wide enough to give distinct images with the goniometer, and then the angle $pp'(001) \wedge (001)$ can be measured. The lines separating the twinning lamellæ are generally very straight, and usually continuous, the lamellæ occasionally terminate abruptly, but oftener taper out to a fine point. This twinning is never made up of less than three bands. The only other twinning visible without the microscope is that according to the pericline law, which may occasionally be seen forming very fine striations on the face g^1(010) nearly parallel to the cleavage *p*(001). Under the microscope it appears that this twinning is much less highly developed than the albite, and appears rather rarely crossing the latter at varying angles depending upon the orientation of the section. Unfortunately it does not appear in the sections which have been made parallel to g^1(010), nor in those perpendicular to n_g and n_p so that its position cannot be exactly determined.

Twinning according to the Carlsbad law is decidedly rare. It occurs, however, combined with the pericline twinning as well as with the common albite twinning. Its composition plane is the same as that of the albite type, (in the cases examined) but its axis of rotation is the vertical crystallographic axis. In no case is it composed of more than two individuals. No other twinning has been found in the plagioclasyte, but in the diabases, where all the types of twinning are beautifully well developed, a single example of the Baveno type has been found. A single anhedron shows four types of twinning, namely the Carlsbad, albite, pericline and Baveno. The section shows the albite and pericline twinning at an angle of 94½° and is therefore approximately parallel to h^1(100); but

it is not strictly perpendicular to the composition plane $e\frac{1}{2}(021)$ of the Baveno twinning. The latter plane makes an angle of 48° with $g^1(010)$ and cuts diagonally across the square crystal, cutting the other twinnings wherever it meets them. The extinction is not symmetrical with respect to the plane $e\frac{1}{2}(021)$, being at 7° on one side and 22° on the other. (See Plate II, Fig. 1).

The hardness of the mineral is 6 to 6.5; its specific gravity varies somewhat; the pure glass-clear fragments show only a slight variation, between 2.696 to 2.709, but oftenest very near 2.701. Large grains often seem lighter than 2.696; even as light as 2.690, but in preparation for chemical analysis not a single one of the small grains floated in liquid of the gravity 2.696. It fuses quietly at about 4, or 4½, to a glass which is colorless and transparent. The flame coloration is the clear red of calcium, but is not intense. With the spectroscope the sodium line is also very distinct. The color of the mineral has already been given, since the color of the mineral and the color of the rock are practically identical. Before the temperature of fusion is reached the cleavages open notably, which has the effect of whitening the mineral, and also makes it easy to crumble it afterward in the fingers. It will be recalled that in its pure condition it is light gray, sometimes greenish, in mass; and when weathered it becomes dull white, varying to greenish, or less commonly to reddish from deposited hematite. The beautiful iridescence common in this feldspar is absent; cleavage surfaces are often bright and glassy. The streak is colorless. When quite pure it is transparent even in mass. In thin section it is perfectly transparent and colorless

This triclinic feldspar never occurs in true automorphic crystal form in the rock under discussion; it is always wholly crystalline and massive; with coarse granitic texture, a conchoidal fracture is easily obtained, but several common cleavages exist. The cleavage parallel to $p(001)$ is much more highly developed than the others, and usually gives bright, lustrous surfaces. It is distinctly better than the cleavage parallel to $g^1(010)$, which is, nevertheless, very well developed for this mineral. The latter cleavage produces faces which are usually much smaller than those parallel to $p(001)$, and are dis-

tinctly inferior as reflecting surfaces. The only other cleavages at all common are those parallel to the faces of the unit prism, that is, $m(1\bar{1}0)$ and $t(110)$, which with the base $p(001)$ give the fundamental form of the older school of French mineralogists. These two cleavages, while occasionally giving surfaces apparently of considerable size, on closer examination are found to give faces which are broken up and irregular. Further, these faces are dull, and only rarely can reflections be obtained from them; when found they are always dim and indistinct. The cleavage $m(1\bar{1}0)$ is slightly better than that parallel to $t(110)$. Only one other cleavage has been observed; it is parallel to $g^{\frac{3}{2}}(150)$, and, while rare, and only giving small surfaces, the reflections are at least as good as those from $m(1\bar{1}0)$.

Crystallographic study. The value of the cleavage angle $pg^1(001)\wedge(010)$, far from being accurately known, has been measured many times by nearly all those who have studied the mineral, with widely varying results, which may be most briefly expressed as follows, with a few determinations of the angles $tg^1(110)\wedge(010)$, $mt(1\bar{1}0)\wedge(110)$ and $pt(001)\wedge(110)$ added merely for reference: (see p. 226).

Labradorite possesses no crystallographic angle easier to measure, or better adapted to accurate measurement, than this cleavage angle $pg^1(001)\wedge(010)$. And yet the variations in the observed value exceed 1°, and two original measurements in exact accord can scarcely be found in the literature of the mineral.

The measurements which have been made on the labradorite from Carlton peak were made with a reflection goniometer of the type now used in the labratories of mineralogy of Paris. (Mallard goniometer.) A hand specimen of the rock was broken into small fragments, as often as possible along these cleavages. The same hand specimen served for all the determinations; in optical properties no indication of any variation in the nature of the feldspar could be found; the chemical composition which corresponds very nearly to the composition expressed by Ab_3An_4 is discussed elsewhere. It has been noted that the cleavage $p(001)$ often gives excellent large reflecting surfaces, while the cleavage $g^1(010)$, while inferior to $p(001)$, is distinctly superior as a reflecting surface to the

DATE	AUTHOR	LOCALITY	Approx. Comp.	Sp. Gr.	pg^1 (001)∧(010)	tg^1 (110)∧(010)	ml $(\bar{1}10)\wedge(110)$	pt (001)∧(110)
1823	G. Rose *	Labrador		2.70	93°30′			
1827	Hessel †				94°30′	119°		115°
1830	Nordenskjold ‡	Ojamo, Finland		2 694	93°28′	119°16′		114°48′
1857	Reusch §	Labrador			93°40′	120°43′		114°4′
1862	Marignac-DesCl. ‖	Etna §§§			93°20′	120°53′	121°37′	
1868	Vogelsang ¶	Labrador			93°50′			
1869	Schrauf**	Labrador			93°30′	117°50′		116°0′
1871	vom Rath ††	Tannenbergsthal Sax. ‖‖‖	Ab_1An_1		94°			
1871	vom Rath ††	Hafnofiord Iceland	Ab_3An_8	2.729	95°15′ 95°25′			
1876	vom Rath ‡‡	Visgerad Hungary	Ab_1An_1	2.66	93°10′ 93°40′			
1876	vom Rath ‡‡	Visgerad ¶¶¶	Ab_1An_1	2.66	93°43′ 93°45′			
?	Tschermak §§				93°56′			
1882	Obermeyer ‖‖	Kiew Russia ****			93°52′	121°33¾′	120°18¼′	
1889	Holland ¶¶	Mull Hebrides	Ab_1An_3	2.720	93°38′			
1894	Fouqué***	Pico Azores	Ab_7An_8	2.696	94°21′			
1898	Naumann-Zirkel †††				93°31′	121°4′	120°18′	
1898	Naumann-Zirkel ‡‡‡				93°48′			
1900	A. N. Winchell	Carlton Peak, Minn.	Ab_3An_4	2.696	94°16′	120°48′	121°15′	114°15′

(For references see next page.)

same cleavage on the labradorite from the other localities from which it has been possible to examine material. Over one hundred cleavage crystals were carefully examined on the goniometer and all those showing good reflections were measured. Of the results obtained a few were discarded as certainly erroneous since they showed a wide variation from any published value. The others are as follows, including a few other angles which were measured merely incidentally as they presented themselves: (see p. 228.)

What is the cause of the variations, which are nearly as wide in the single series of measures, not only from the same locality, but from the same hand specimen, as those shown by the table of measures by various authors from widely separated localities? They are certainly not due to the apparatus used, as it has been repeatedly tested with other minerals, and found very satisfactory; neither are they entirely due to the inexperience of the operator, since one of the most exceptional

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*Rose: Gilbert Ann. LXXIII. 1823, p. 194.

†Hessel: Kastner's Archiv. X, 1827, p. 274. Ref. Schrauf: Sitzb. Akad. Wissensch. Wien. LX. 1869.

‡Nordenskjold: Pogg. Ann. XIX, 1830, p. 181. Measurements made with Wollaston goniometer.

§Reusch: Pogg. Ann. CXX, 1857, p. 96.

‖Marignac in Des Cloizeaux. Min. 1862, p. 303.

¶Vogelsang: Archives Néerlandaises III, 1868.

**Schrauf: Sitzb. Akad. Wissensch. Wien. LX. 1869, p. 996.

††vom Rath: Pogg. Ann. CXLIV. 1871, p. 219.

‡‡vom Rath: Ber. Akad. Berlin. XLI, 1876, p. 147.

§§Tschermak: See Dana Min. 1892, p. 326.

‖‖Obermayer Zeits. Kr. III, 1893, p. 66.

¶¶ Holland: Min. Magazine. London. 1889. VIII. p. 154.

***F. Fouqué: Bull. Soc. Fr. Min. XVII. 1894, p. 343.

†††Naumann and Zirkel: Elem. Min. 1898, p. 730.

‡‡‡Naumann and Zirkel: Elem. Minn. 1898, p. 721.

§§§Several analyses from this locality show wide variations, so that the composition of the material measured is uncertain; I have been unable to find any evidence that the material measured was analyzed. However, the measure of $mt(1\bar{1}0) \wedge (110) = 121° \ 37'$ is said to have been on feldspar of the composition Ab_3An_4.

‖‖‖The value is from the measurement pp'(001) ∧ (001) = 172°.

¶¶¶These values are also from measurements of twinning faces.

****Material from this locality gave Segeth the composition $Ab_7 An_8$ nearly. It is remarkable that Obermayer gives only four measures: 93° 43', 93° 44', 93° 48' and 93° 50', and then concludes that the true value is 93° 52'! And this value, which was not once actually observed by Obermayer, is the basis of the axial elements as given by nearly all the best mineralogies of the present time.

No.	Sp. Gr.	*pg*¹ (001)∧(010)	*mt* (1̄10)∧(110)	*tg*¹ (110)∧(010)	*pt* (001)∧(110)	*pg*½ (001)∧(150)	*pp'* (001)∧(001)
1	2.700	94° 24′	....	....	....	....	....
2	2.697	94° 33′	....	....	....	....	....
3	2.697	94° 25′	....	....	....	....	....
4	2.701	94° 19′	....	....	....	....	171° 24′
5	2.701	94° 15′	....	....	....	....	....
6	2.699	94° 7′	....	....	....	....	171° 45′
7	2.701	94° 29′	....	....	....	....	171° 2′
8	2.701	94° 27′	....	120° 49′	....	....	....
9	2.701	94° 29′	....	120° 47′	....	....	....
10	2.700	94° 28′	....	....	....	....	....
11	2.699	94° 13′	....	....	....	....	171° 33′
12	2.702	94° 20′	....	....	....	....	171° 20′
13	2.701	94° 8′	....	....	....	....	....
14	2.703	94° 30′	....	....	....	....	....
15	2.699	93° 56′	....	....	....	....	....
16	2.697	93° 40′	....	....	....	....	....
17	2.700	94° 6′	....	....	114° 22′	....	....
18	2.703	93° 54′	....	....	....	....	....
19	2.700	94° 14′	....	....	114° 17′	....	....
20	2.703	94° 10′	121° 23′	....	....	....	....
21	2.702	94° 11′	....	....	....	....	....
22	2.700	94° 10′	121° 23′	....	....	....	....
23	2.700	94° 21′	121° 24′	....	....	....	....
24	2.701	94° 19′	....	....	....	....	....
25	2.700	94° 5′	121° 24′	....	....	....	....
26	2.700	94° 40′	....	....	....	....	....
27	2.697	94° 25′	....	....	....	....	....
28	2.700	....	121° 13′	120° 48′	....	....	....
29	2.700	....	120° 54′	....	....	....	....
30	2.700	....	121° 23′	....	114° 9′	....	....
31	2.697	....	....	....	....	102° 6′	....
32	2.700	....	121° 3′	....	....	....	....
Average..		94° 16′	121° 15′	120° 48′	114° 16′	102° 6′	171° 25′

measures (No. 14), was kindly verified by Prof. A. Lacroix, who found 94° 31′. The cause of the variations must be sought in the mineral itself; an attentative examination shows that while the face *p*(001) is usually perfectly plane in the feldspar from Carlton peak, the face g^1(010) is sometimes slightly irregular, being composed of two (or, less commonly, even more) of the planes such as are often called "vicinal." It is further to be noted that these planes vary more or less in the angle which they make with *p*(001); in extreme cases this variation amounts even to one degree. Further, these planes, while sometimes about equal in size and lustre, are more commonly unequal, but either one may be the larger and brighter, and either one may even entirely obliterate the other, without that fact having any visible influence upon its own position. Thus we find crystals showing a single image from the face g^1(010) and giving an angle as high at 94° 40′, and others showing also a single image from g^1(010), and giving an angle as low as 93° 40′, though both are quite exceptional. This probably explains also the wide variations in the measures obtained by other observers.

It may be at once suggested that the same cause has operated to produce the remarkable average, *i. e.* that the "vicinal" plane forming the larger angle with *p* (001) being accidentally more common than the other, the average is therefore considerably too high. But is this the case? As physical laws are so often not mathematically exact, it is conceivable that it should occur in rare cases, but it is contrary to reason to suppose that it could become the general rule in a hundred cases. Furthermore, if such a false plane could supplant the true cleavage plane in many cases, it could hardly at the same time affect the twinning plane which in the nature of the case, would remain parallel to the true plane. Now the albite twinning as noted elsewhere, occasionally furnishes wide lamellæ by means of which the angle pp'(001) ∧ (001) can be measured with considerable precision. It is evident that the angle pg^1 (001) ∧ (010) can be very readily calculated from the angle pp'(001) ∧ (001). Indeed one-half of the latter angle is equal to the supplement of the former. The average value obtained for pp'(001) ∧(001) was 171° 25′; the supplement of the half of this equals 94° 17½′, which agrees very closely with the

average observed value of $pg^1(001) \wedge (010)$ The comparison can even be carried to the individual cases: $pg^1(001) \wedge (010)$ calculated from $pp'(001) \wedge (001)$ with crystal number four equals 94° 18′, while the observed value is 94° 19′; the calculated value with number six is 94° 7½′, while the observed value is 94° 7′; for number seven and number twelve the calculated and observed values are identical; for number eleven the observed value is 94° 13′, while the calculated value is only half a minute larger.

Therefore it seems evident that the real value of the angle $pg^1(001) \wedge (010)$ is actually variable, because the position of the plane $g^1(010)$ is variable; and that its real average value in the locality studied is near 94° 16′. We now have the explanation of the so called "vicinal" planes; they are, in the case in hand, representatives of the plane $g^1(010)$ in its variable positions. It being once admitted that the position of the plane $g^1(010)$ really varies, it is evident that the only way to obtain a representative value is to take the average of a large number of determinations.

The importance of this crystallographic measure lies in its bearing upon the theory of the continuity of the plagioclase feldspars as isomorphous mixtures of albite and anorthite. For, according to this theory, all the other triclinic feldspars must be strictly intermediate in all their characters, chemical, physical, and optical, between these two end compounds. Now the angle $pg^1(001) \wedge (010)$ in albite is 93° 36′, while in anorthite it is 94° 10′. These values are well established and at the present time are called in question by no one. If a labradorite occurs with the angle $pg^1(001) \wedge (010)$ greater than 94° 10′ it is conclusive evidence of the inaccuracy of the theory. Of course, that a few exceptional measures of the angle should exceed 94° 10′ could easily be explained as due to uneven surfaces on $g^1(010)$, but that a series of twenty-five measures on carefully selected material should give an average over 94° 10′ is not so easily explained.

A comparative crystallographic study of labradorite from various other localities confirms very clearly the conclusion that the position of the face $g^1(010)$ is variable, and it shows further that the variation is undoubtedly due to very slight variations in the chemical composition.

Thus labradorite from Kamenoi Brod, Russia, possesses an unusually easy cleavage parallel to g^1(010), but both cleavages are rather uneven; the images are nearly as good as those from the Minnesota feldspar. The Russian locality furnished the following series of measures: pg^1(001) ∧ (010)=93° 57′, 94° 7′, 93° 49′, 93°58′, 94 °7′, 94° 2′, 94° 5′, 93° 56′, 94° 15′, 94° 0′, 93° 44′, 94° 0′, 94° 0′, 93° 40′, 94° 8′, 93° 55′, 93° 50′, 93° 56′, 93° 50′, 94° 14′, 93° 45′ or an average of 93° 58′ with variations between 93° 35′ and 94° 1.5′. The extinction angle on p(001) varies from 6½° to 11°, averaging nearly 9°; on g^1(010) the extinction varies between 20° and 24° with an average about 21½°; the specific gravity is 2.697-2.700; the composition must therefore be very near $Ab_7 An_8$, and the only analysis known from this locality gave very nearly that composition.

Another specimen of labradorite from Kamenoi Brod (near Kiew), Russia, gave images, bright, but often blurred. About fifty crystals were examined from this locality and the following measures taken: pg^1(001) A(010)=94° 12′, 93° 37′, 93° 52′, 93° 57′, 93° 40′, 94° 14, 93° 57, 93° 47′, 93° 52′, 93° 50′, 93° 53′, 93° 14′, 93° 36′, 93° 55′, 94° 9′, 94° 10, 94° 13′, 93° 54′, 93° 57′, 93° 48′, 93° 51′, 94° 4′, 93° 42′, 93° 55′, that is an average of 93° 56′, with variations between 93° 36′ and 94° 14′. The extinction angle on p(001) varies from 21° to 24° with the average about 23°; on g^1(010) it varies* from 6° to 9°, averaging about 7½°; the specific gravity varies between 2.696 and the composition is therefore again very near Ab_7An_8.

Labradorite from the classic locality on the east coast of Labrador occassionally gave good images; the measures result: pg^1(001) ∧ (010) = 93° 59′, 93° 52′, 94° 14′, 93° 45′, 93° 44′, 94° 4′, 93° 39′, 93° 59′, 93° 58′, 93° 42′, 93° 45′, 93° 59′, 93° 45′, 94° 13′, 94° 0′, which furnish an average of 93° 54½′. The extinction angle on p(001) varies from 22° to 25°, but averages very nearly 23°; on g^1(010) it runs from 6° to 10° averaging about 7½°; the specific gravity varies from 2.696 to 2.698. The composition is again very near Ab_7An_8 perhaps slightly more acid than the preceding.

Finally a single cleavage crystal† from Poulkouka valley,

*This angle very rarely is about 2°; also about 12°.

†Other crystals from the same locality were more acid.

Russia, (near St. Petersburg), gave the following measures: $pg^1(001) \wedge (010) = 94°19', 94°7', 94°16', 94°4'$, averaging 94° 12'. This crystal has a specific gravity of 2.701; and the extinction on $g^1(010)$ is 25°, and on $p(001)$ it is 9½° to 11°. The composition is evidently near Ab_3An_4.

Persistant attempts were made to obtain similar measures on material from several other localities, namely, Etna, Italy; Ojamo, Finland; lake Champlain, New York, and Wilmington, Delaware, but the images from cleavage faces were too confused to permit any reliable measures, though the values obtained only confirmed the general conclusion that a remarkable increase in the angle $pg^1(001) \wedge (010)$ occurs as labradorite becomes more basic. It is especially regretted that no good measures could be obtained with the labradorite from Etna, since that was the only material of volcanic origin examined, but the images were especially bad, being always faint and blurred, or multiple. The material from Ojamo, Finland, gave images from $p(001)$ which, though bright, formed a continuous series of images of equal brightness extending over several degrees. Such measures as could be obtained were frequently 90° to 91°, showing that the cleavage $p(001)$, instead of following the zigzag of the albite twinning, cut irregularly across it.

The exact chemical composition of the material serving for previous goniometric measurements is only known in a few cases, but the double determinations of this sort, indicate in general a rapid increase of the angle $pg^1(001) \wedge (010)$ as the feldspar becomes more basic, and an increase beyond the value for anorthite for feldspars between Ab_7An_8 and Ab_1An_2. Arranging in order of basicity, the following table results:

It is unfortunate that so few of those, who have made careful determinations of the value of angle $pg^1(001) \wedge (010)$, have made any chemical analysis of the material used. The few analyses it has been possible to find are far from satisfactory; thus, it will be seen at once that the high per cent of potassium in the first analysis has distinctly decreased the specific gravity, and probably is the cause of the low silica; the calcium oxide is the most characteristic number. The specific gravity of the second seems distinctly too high; the value of the cleav-

Approx. Comp.	Author	Locality	$pg^1(001) \wedge (010)$	Sp.Gr.	SiO_2	Al_2O_3	CaO	Na_2O	K_2O	
Ab_1An_1	Vom Rath	Visgerad, Hun.	93°10′ 93°45′ 93°40′ 93°43′	2.66	50.40	30.65	10.53	3.27	3.36	H_2O = 1.69 Sum = 99.90
Ab_1An_1	Vom Rath	Tannenbergsthal	94°	2.711	53.61	29.68	10.96	4.96	1.15	H_2O = .65 Sum = 99.76
Ab_1An_1	Fouqué	Pico, Azores	94°21′	2.696	54.9	29.3	10.25	5.35	0.07	Fe_2O_3 = .6 MgO = .06 Sum = 100.53
Ab_3An_4	A. N. Winchell	Minnesota	94°16′	2.701	53.38	29.70	11.90	4.30	0.46	Fe_2O_3 = .21 H_2O = .37 Sum = 100.42
Ab_2An_3	Scharizer	Jan Mayan	94°	2.703	52.68	29.45	12.18	3.88	0.58	Fe_2O_3 = .28 H_2O = .35 Sum = 100.00
Ab_2An_3	Vom Rath	Hafnofiord, Icel'd.	95°15′ 95°25′	2.729	54.23	29.64	12.01	4.41	trace	MgO = .11 H_2O = .07 Sum = 100.40
Ab_1An_2	Holland	Mull, Hebrides	93°38′	2.720	50.80	31.54	12.83	3.96	trace	Heat = .52 Sum = 99.65

age angle found by Fouqué is only a trifle too high to take its place in the regular increasing series; the alkalies of his analysis indicate Ab_1An_1, but the alumina, silica, and specific gravity all point toward Ab_7An_8; on the other hand the determination of Scharizer* is a decided exception to the general rule. Vom Rath's third analysis is also unsatisfactory; the calcium and sodium correspond very closely with Ab_3An_4, but the gravity is much too high. Finally, Holland's calcium determination is too low to correspond with the rest of the analysis.

It may be worth while to note that the little evidence we have would indicate that Nordenskjold's feldspar would take its place near Ab_1An_1 in the series, and Abich† and Ricciardi‡ have published analyses indicating that Marignac-Des Cloizeaux's material was quite possibly Ab_1An_1. The only analysis known of the feldspar from near Kiew gave a result very near Ab_7An_8, so that Obermayer's values between 93° 43′ and 93° 52′ would take a natural place in the series. The four values from the coast of Labrador would also fall nearly in their regular places, since many analyses show that the feldspar in that locality is usually very near Ab_1An_1, and may even be slightly more acid, while it is rarely found more basic than Ab_7An_8. It is therefore evident that the value of the angle $pg^1(001)\wedge(010)$ in the feldspar Ab_1An_1 is very near 93° 30′. The values found for the various plagioclases can probably be arranged as follows:

Authority	Locality	Value	Composition
G. Rose	Labrador	93°30′	Ab_1An_1
Reusch	Labrador	93°40′	
Schrauf	Labrador	93°30′	
Marignac-Des Cloizeaux	Etna	93°20′	
Nordenskjold	Ojamo	93°28′	
Vom Rath	Visgerad	93°10′	
Vom Rath	Visgerad	93°40′	
Vom Rath	Visgerad	93°43′	
Vom Rath	Visgerad	93°45′	
	Average	93°32′	Ab_1An_1

*His measure may be simply an approximation, as he does not say how it was made; it is, indeed, given rather incidentally.

†Abich: Pogg. Ann. 1840. L. p. 347.

‡Ricciardi: Gazz. Chim. Ital. 1881, p. 138.

Vogelsand	Labrador	93°50′	Ab_7An_8
Obermayer	Kiew	93°52′	
A. N. Winchell	Labrador	93°54′	
A. N. Winchell	Kiew	93°56′	
A. N. Winchell	Kamenoi Brod	93°58′	
Vom Rath	Tannenbergsthal	94° 9′	
Fouqué	Pico	94°21′	
	Average	93°59′	Ab_7An_8
A. N. Winchell*	Carlton Peak	94°16′	Ab_3An_4
Scharizer	Jan Mayen	94°	Ab_2An_3
Vom Rath	Hafnofiord	95°15′	
Vom Rath	Hafnofiord	95°25′	
	Average†	94°53′	
Holland	Mull, Hebrides	93°38′	Ab_1An_2

These results may be represented graphically in connection with the values ordinarily accepted for the other feldspars, as follows:

1. Albite pg^1 (001)$\wedge$(010) = 93° 36′, determined by Marignac and Des Cloizeaux on material from St. Gotthard, and generally accepted, though Tschermak seems inclined to prefer a smaller angle, as low as 93° 10′ (see Tschermak: Min. 1894. p. 472, but cf. p. 466).

2. Oligoclase, pg^1(001)$\wedge$(010) 93° 28′, determined by vom Rath on feldspar from Vesuvius of composition nearly Ab_4An_1, but analysis somewhat discordant; this is accepted by all the best mineralogies of the present time, though they also accept Tschermak's theory with which it is clearly discordant.

3. Andesine, pg^1(001)$\wedge$(010) = 93° 46′, determined by vom Rath on crystals from Sardinia containing 60.2% SiO_2 and showing certain optic properties characteristic of andesine. Universally accepted.

4. Labradorite, pg^1(001)$\wedge$(010) = 93° 32′; average of nine determinations which have been made hitherto on material which was probably of the composition Ab_1An_1. (See above.)

5. Labradorite, pg^1(001)$\wedge$(010) = 93° 52′, accepted as correct by Obermayer after four measurements resulting: 93° 40′, 93° 44′, 93° 48′, and 93° 50′, on material unanalyzed, but probably near Ab_7An_8; accepted by most authorities at present.

6. Labradorite, pg^1(001)$\wedge$(010) = 93° 59′, average of seven determinations which have been made on material of the composition Ab_7An_8, nearly. (See above.)

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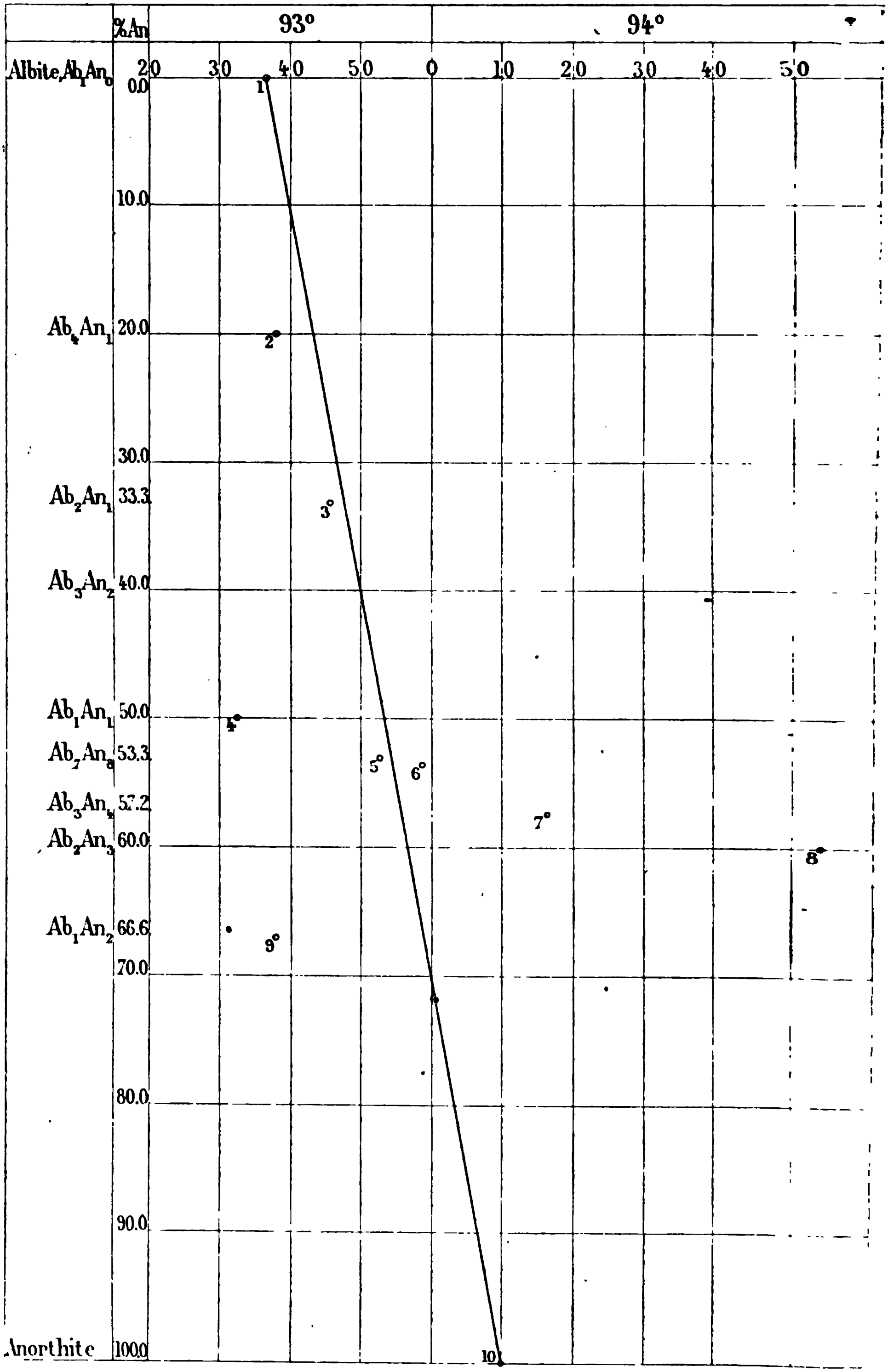
*One might add to this: A. N. Winchell, Poulkouka pg^1(001)$\wedge$(010) =94° 12′.

†Without the value of Scharizer the average would be 95°20′



The angle pg^1 (001) ∧ (010) in the plagioclases.

7. Labradorite, $pg^1(001) \wedge (010) = 94° \ 16'$, as determined by the writer on feldspar from Carlton peak, Minnesota, of the composition Ab_3An_4, nearly. (See above.)

8. Labradorite, $pg^1(001) \wedge (010) = 94° \ 53'$, average of the three determinations which have been made hitherto on material of the composition $An_2 \ An_3$, nearly. (See above.)

9. Labradorite, $pg^1(001) \wedge (010) = 93° \ 38'$, determined by Holland on material from Hull, one of the Hebrides islands, of the composition Ab_1An_2, nearly. (See above.)

10. Anorthite $pg^1(001) \wedge (010) = 94° \ 10'$, determined by Marignac and Des Cloizeaux on crystals from Vesuvius; chemical composition not given; result confirmed by Koksharow and universally accepted.

Since no measures have been made hitherto (so far as known to the writer) on the feldspar Ab_3An_4, it may be of interest to present the result of various angles and axial elements calculated on the basis: $pg^1(001) \wedge (010) = 94° \ 16'$, $tg^1(110) \wedge (010) = 120° \ 48'$; $mt(1\bar{1}0) \wedge (110) = 121° \ 15'$; and $pt \ (001) \wedge (110) = 114° \ 16'$:

$$a : b : c = .63314 : 1. : (.5+)$$

$\alpha = yz = 93°20\tfrac{1}{2}'$	$A = X = 94°16'$
$\beta = zx = 115°48'$	$B = Y = 115°52'$
$\gamma = xy = 90°30'$	$C = Z = 91°51'$
$g^1m(010) \wedge (1\bar{1}0) = 117°59'$	$mh^1(1\bar{1}0) \wedge (100) = 153°52'$
$g^1h^1(010) \wedge (100) = 91°51'$	$th^1(110) \wedge (100) = 151°3'$
$g^1g^{\frac{3}{2}}(010) \wedge (150) = 160°41'$	$ph^1(001) \wedge (100) = 115°52'$
$mt(\bar{1}\bar{1}0) \wedge (110) = 121°13'$	$pm(001) \wedge (1\bar{1}0) = 111°31'$

$$pg^{\frac{3}{2}}(001) \wedge (150) = 94°12'$$

$$p^1g^{\frac{3}{2}}(001) \wedge (150) = 102°19' \text{ (measured } = 102°6')$$

$$pp'(001) \wedge (001) = 171°28' \text{ (measured } = 171°25')$$

Optic properties of labradorite. The *refractive indices* were determined by the method of total reflection with a Bertrand apparatus. Much to the regret of the writer, it must be admitted that the limit of error is as high as .002, on account of defective apparatus. The results follow:

$$n_g = 1.5705$$
$$n_m = 1.5660$$
$$n_p = 1.5626$$

$n_g - n_m = .0045$	direct measure	$= .0046$
$n_m - n_p = .0034$	" "	$= .0036$
$n_g - n_p = .0079$		

$$N = \frac{n_g + n_m + n_p}{3} = 1.566$$

Fouqué has made very accurate measurements of the refractive indices of a few speciments of "labrador-bytownite" from the volcanic rocks. His results are:

Composition									
SiO_2	Al_2O_3	CaO	Na_2O	K_2O	Sp. Gr.	Locality	n_g	n_m	n_p
53.3	30.1	11.4	5.1	.1	2.708	Vellas,* Ile St. Jorge	1.5677	1.5628	1.55[illegible]
53.4	29.4	12.5	4.8	.2	2.710	Capello, Fayal	1.5689	1.5639	1.5611
54.5	29.8	11.4	4.5	.3	2.698	Besseyre, Hte Loire		1.5637	1.5617
53.7	29.6	11.8	4.9		2.703	Theoretical composition of Ab_3An_4.			
53.38	29.70	11.90	4.30	.56	2.701	Carlton Peak, Minn†	1.5705	1.5660	1.5626

It will be noted that the indices of the American labradorite are slightly higher than those determined by Fouqué.

Birefringence. The measured indices of refraction indicate at once the birefringence, but results much more accurate are readily obtained by the direct measure of the birefringence. This was accomplished by means of two sections perpendicular to n_g and n_p. The apparatus used was the "*comparateur*" of Michel Lévy, and it is believed that the limit of error does not exceed .0002; the results obtained were

	Direct measure	Measure of the indices
$n_g - n_m =$	.0046	.0045
$n_m - n_p =$	.0036	.0034
$n_g - n_p =$	.0082	.0089

Fouqué made no direct measures of the birefringence of the feldspars, but the following values are derived from his measures of the indices of refraction by the method of the prism:

Locality	Composition	$n_g - n_m$	$n_m - n_p$	$n_g - n_p$
Besseyre, Haute Loire	Ab_3An_4	.....	.0030	.....
Capello, Fayal	Ab_3An_4	.0050	.0028	.0078
Ile St. Jorge, Azores	Ab_3An_4	.0049	.0031	.0080
Carlton peak, Minn.	Ab_3An_4	.0046	.0036	.0082

It will be seen that the difference between the partial birefringences is much less (.0010 instead of .0018 and .0022) in the case of the Carlton peak labradorite; this corresponds with the larger optic axial angle in the latter. Further the maxi-

*Contains also traces of Fe_2O_3, and .1 of MgO.
†Contains also traces of MgO, and .21 of Fe_2O_3.

mum birefringence is greater in the Minnesota feldspar, but the difference is only slight.

The mineral is positive, since (n_g-n_m) is greater than (n_m-n_p).

Angle of the optic axes. The value of the true angle of the optic axes calculated by the aid of the formula:

$$\tan^2 V = \frac{n_m - n_p}{n_g - n_m}$$

gives the following results: $2Va=82°\ 0'$.

The direct measure of the optic angle was made from two sections perpendicular respectively to n_g and n_p with the conventional apparatus. The sections were immersed first in essence of cinnamon with an index for sodium light of 1.609 and then in distilled water. While this method gives the best results at present known, it is not possible to avoid a maximum possible error of about 20′, and, with only ordinary precautions, this may easily rise to 30′ or 40′. Monochromatic light was used: sodium for yellow, lithum for red, and thallium for green. It was found that the measured value of the optic angle varies in different parts of a single crystal, since successive measures in the same spot showed variations not exceeding ten minutes, while measures in different parts of a single crystal varied as much as 30′ or 40′ (in measuring the obtuse angle even rising sometimes to one degree). Since the crystals show no sign of a zonal structure, nor any variation in extinction under the microscope, it is probable that the variations are due either to the existence of thin twinning lamellæ, or to defects in the preparation or adjusting of the section.* Therefore in order to obtain comparable values for the different colors, the optic angle was measured on the same spot with thallium, lithium, and sodium successively. The results may be tabulated as follows:

	Thallium	Sodium	Lithium
$2H_a$ =	81°36′	82°0′	82°24′
$2H_o$ =	94°10′	94°0′	93°43′

Whence from the formula: $\tan V_a = \frac{\sin H_a}{\sin H_o}$

$2V_a$ =	83°29′	83°47′	84°9′

*Mallard has shown (see Traité de Crystallographie II. p. 431) that if the section varies 2° from the plane perpendicular to the bisectrix, it will cause an error of 40′ in the value of 2E in the case of pyroxene.

The measures in distilled water resulted as follows:

$2\,Aq_a$ =	104°4′	104°22′	104°36′
$2\,Aq_o$ =	124°16′	124°0′	122°40′

Whence, from the same formula:

$2\,V_a$ =	83°27′	83°38′	84°5′

The angles in distilled water, being larger, were more difficult to measure exactly, and are therefore less exact than those in the oil.

The following extreme variations were observed :

	Thallium	Sodium	Lithium
$2\,H_a$	81°28′	81°48′	82°19′
	81°41′	82°16′	82°25′
$2\,H_o$	94°5′	93°43′	93°31′
	94°15′	94°45′	93°56′
$2\,Aq_a$	104°4′*	104°20′	104°31′
		104°23′	104°40′
$2\,Aq_o$	124 16′*	123°54′	122°20′
		124°26′	123°0′

It may be noticed that the results accepted above are not always the average of the extremes; this is due to the fact that when a single part of the section gave a result notably different from those obtained from the other parts of the same crystal, that result was considered abnormal, and was not considered in finding the average, though it is given in the variations.

If now we examine the results obtained previously we find that they are not numerous; indeed it has been possible to find only the following:

					Chemical Composition.				
Apx. Comp.	Sp.Gr.	Locality	Authority	$2V_a$	SiO_2	Al_2O_3	CaO	Na_2O	K_2O
Ab_3An_4	2.698	Besseyre, Hte. Loire	Fouqué	76°16′	54.5	29.8	11.4	4.5	.3
Ab_3An_4	2.708	Ile St. Jorge. Azores	Fouqué	76°16′	53.3	30.1	11.4	5.1	.1
Ab_3An_4	5.710	Capello, Fayal	Fouqué	77°0′	53.4	29.4	12.5	4.8	.2
Ab_3An_4	2.705	Capello, Fayal	Fouqué	79°40′	54.2	30.3	11.8	3.9	.2
			Average	77°16′					

The angle (83° 47′) found in the labradorite from Carlton peak is therefore more than four degrees greater than any found by Fouqué, and is 6° 31′ greater than the average of his

*Only one measure made.

measures. This extraordinary difference can not be explained on the ground of difference in chemical composition since the Minnesota plagioclase is not appreciably more basic than those studied by Fouqué.* Since his measures were all made on feldspars from the volcanic rocks, it seems probable that the optic angle is distinctly greater in labradorite of the deep-seated rocks than in the corresponding labradorite of the volcanic rocks. It will at least be interesting to examine this question further as the measures of the optic angle on material of known composition increase in number. It is well known that for orthoclase† the angle of the optic axes is generally very small in the mineral derived from the volcanic rocks, and that it may be, on the contrary, quite large in orthoclase of the granitic rocks.

Dispersion. The values of the optic angles for the different colors determine at once that $\rho > \upsilon$ about n_g the acute bisectrix, and $\rho < \upsilon$ about n_p.

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*The following measures on the labradorite Ab_1An_1 and on material of composition not exactly known, have been made:

Comp.	Sp. Gr.	Locality	Author	2Va	2Ha	2G
Ab_1An_1(?)	2.694	Chenavari	Fouqué	77°0′		
do	2.696	Pico (Azores)	Fouqué	77°6′		
do	2.695	St. Lucia, Pico	Fouqué	77°36′		
do	2.698	Lava of 1720, Pic.	Fouqué	77°38′		
do (?)	2.700	Peak of Pico	Fouqué	78°34′		
do (?)	2.688	Rochesauve	Fouqué	80°40′ 82°25′		
Ab_3An_4(?)		Labrador	DesCloizeaux	82°6′	89°10′	
AbAn (?)		Djupivogur, Iceland	DesCloizeaux	81°44′	88°15′	
Ab_7An_8(?)		Ojamo, Russia	DesCloizeaux	80°41′	87°5′	
do		do	do	79°12′	85°29′	
do		do	do	78°34′	84°43′	
Ab_1An_1		Ojamo, Russia	Schuster	79°24′		82°36′
do		do	do	78°16′		81°24′

It should be noted that the measures of Des Cloizeaux were made in red light and are therefore not exactly comparable with the others which were made in yellow light. However the difference could scarcely exceed 30′. Fouqué's material was all from volcanic rocks, with the possible exception of that from Rochesauve; the others were all from deep-seated rocks, with the possible exception of that from Iceland. These measures tend to confirm the view that the optic angle in labradorite of the deep-seated rocks is notably greater than in the corresponding labradorite of the volcanic rocks.

†See Lacroix: Minéralogie de la France, II. p. 68.

The interference figure in convergent light plainly shows the same fact, since blue is found on the concave side of the hyperbolas in sections perpendicular to n_g, and on the convex side in sections perpendicular to n_p. Further, the examination of the interference figures shows that, besides this dispersion of the optic axes, there is a weak dispersion of the bisectrices. For, when the black cross is formed, blue is found on one side of the bar in one optic axis, and on the other side of the bar in the other optic axis. This is evidence of crossed dispersion of the bisectrices. Further, one optic axis is strictly circular, while the other is slightly elliptical; therefore we have slight inclined dispersion. Neither kind of dispersion of the bisectrices is strong enough to produce any marked effect on the colored rings which are nearly uniform in tint on all sides.

The position of the optic elements has been the object of considerable work by several writers, but owing often to the absence of reliable analyses of the material studied, the results obtained are discordant, and in general unsatisfactory. Fouqué, indeed, has obtained reliable results, but his studies were confined to the volcanic rocks, with a single exception. That one exception gave him results differing notably from his other values. The position of the optic elements is determined by measurements of the extinction angles in sections of definite orientation. These sections are usually, and preferably, those perpendicular to the two bisectrices, and those parallel to the two good cleavages, p (001), and g^1 (010).

Angles of extinction parallel to the easy cleavage. The angles of extinction in the faces p(001) and g^1(010) are of much importance from the point of view of the determination of the feldspars.

In the case of the plagioclasyte from Carlton peak, sections and cleavage fragments parallel to g^1(010) give extinction angles varying from—23° to—27°, but the commonest angle is very near—26°. Sections and cleavage pieces parallel to p(001) also show variations, in this case, between—10° and—15° but usually very near—12°.

These values are entirely comparable to those obtained by Fouqué, which are given on the following page.

Angles of extinction perpendicular to the bisectrices. Fouqué has shown the importance of the value of the angles of

extinction in sections perpendicular to each one of the bisectrices. His numbers are indeed entirely characteristic for any given feldspar, and constitute therefore an important diagnostic. In the case of the Carlton feldspar they are all the more important since all the plagioclases studied by Fouqué were derived from volcanic rocks, and therefore differ in origin from the one here studied.

Two sections of the labradorite from Carlton peak perpendicular to n_g and n_p were prepared M. Ivan Werlein. Perpendicular to n_p the extinction is at an angle of 57° to 57° 30′, but the bisectrix is not absolutely centered, and the measure is therefore slightly inaccurate. On the contrary, the bisectrix n_g is very well centered, and the extinction angle is 37° to 37° 30′.

A comparison with the results of Fouqué can be tabulated as follows:

			Extinction angle			
			parallel to		perpendicular to	
Composition*	Sp. Gr.	Locality	g^1(010)	p(001)	n_g	n_p
Ab_2An_4......	2.698	Besseyre, Hte. Loire			31°	59°
Ab_2An_4......	2.710	Capello, Fayal			32°	58°
Ab_3An_4......	2.709	Ile St. Jorge, Azores	21°-22°	8°	33°	59°
Ab_4An_4......	2.705	Capello, Fayal	26°-28°	12°-13°	35°	58°
Ab_2An_4......	2.701	Carlton Peak, Minn.	26°	12°	37°	57°30,
Ab_3An_4 Theoretical angles deduced from the diagrams of Michel Lévy.			24°	9°	30°	58°

The extinction angles parallel to g^1(010) and p(001) are therefore entirely comparable to the higher values found by Fouqué. The extinction† perpendicular to Tn_p is slightly different, but it is not strictly accurate; the extinction perpendicular to Sn_g is distinctly higher than the values obtained from the volcanic rocks. Can this be due again to a difference

*For exact composition see page 238; the composition of the Minnesota labradorite will be given later.

†F. Fouqué: Bull. Soc. Min. France. vol. XVII. 1894. M. Fouqué designates by S and T the sections respectively perpendicular to the acute and to the obtuse bisectrix, and these letters are followed by n_g or n_p, according as the bisectrix is positive or negative. Sn_g therefore means the section perpendicular to the acute bisectrix, which is positive.

in the characters of labradorite in the two classes of rocks? Or is it due simply to a greater basicity in the particular fragment serving for the measure? Several other examinations of the labradorites of the deep-seated rocks can alone decide the question.

The comparison with the theoretical angles established by Michel Lévy for the labradorite Ab_3An_4 leads to the same results;the angle of extinction in S*ng* is remarkably larger in the Minnesota plagioclase than the theoretical value.

Angles between planes perpendicular to bisectrices and cleavage faces. It is only rarely possible to determine the position of the optic elements by direct goniometric measurements of the angles between an artificial plane perpendicular to one of the bisectrices, and some of the natural planes of the mineral.. In those cases when the natural faces are not wholly destroyed in the making of the artificial plane, the section is usually so thin that very little accuracy can be expected. The Minnesota feldspar has afforded only the merest approximations. The plane S*ng*, makes an angle of about 47° with *p*(001); while the surface T*np* makes an angle of about 66° with *p*(001), and about 69° with g^1(010). No similar measurements have been made to the knowledge of the writer except those by Descloizeaux, and Fouqué, which, however, are mutually complementary. Omitting those not accompanied by analyses, they can be presented as follows:

		Angle between S*ng* or T*ng* and			Angle between T*np* or S*np* and	
Name	Approximate Composition	*p*(001) DesCl	*p*(001) Fouqué	g^1(010) Fouqué	*p*(001) Fouqué	g^1(010) Fouqué
Albite	Ab_1An_0	78°–81°	78°		89°	70°
Oligo.-Albite	$Ab_{12}An_1$	83°				
Oligo.-Albite	Ab_8An_1	86°30′	87°			
Oligoclase	Ab_4An_1	78°				
Oligo.-Andesine	Ab_3An_1	72°	74°			
Andes.-Oligo.	Ab_3An_2	68°	68°			
Andesine	Ab_4An_3	62°				
Labradorite	Ab_1An_1	56	53°	31	79°–84	74°
Labradorite	Ab_3An_4		49°30′		71°	65°
Anorthite	Ab_1An_{12}		35°	50°	58°	53°

Maximum angle of extinction in the zone of symmetry perpendicular to g^1 (010). The mineral is so coarse that an indefinite number of thin sections would be necessary to determine accurately the maximum equal extinction in the zone perpendicular to g^1 (010), but it is certainly not essentially different from that found in the labradorite of the diabases (namely 38°).

To summarize the results of the study of the optic properties of labradorite, we have found that the indices of refringence are higher than those determined by Fouqué on plagioclase of the same chemical composition from the volcanic rocks. The maximum birefringence likewise is greater, but these two differences are wholly negligible when compared with the difference in the values of the optic angle. The value found in the Minnesota type seems to indicate that the optic angle is distinctly greater in deep-seated than in volcanic rocks. But more measures are needed to establish this beyond question. The same is true of the greater extinction angle observed perpendicular to n_g; the other extinction angles present no marked differences.

(*To be continued.*)

NOTES ON THE FAUNA OF THE BURLINGTON LIMESTONE AT LOUISIANA, MO.

By R. R. ROWLEY, Louisiana, Mo.

Blastoidea.

Perhaps no other known Burlington locality is so prolific in and yields such a varied fauna of blastoids as Louisiana. There are twenty valid species and a number of well marked varieties.

The commonest species and one of greatest range is Cryptoblastus melo which is found sparingly from the very bottom of the 1st., through the 2nd., 3rd. and 4th. to the very top of the 5th division of the Lower Burlington, being plentiful only near the top of the 4th. division, where in a narrow band, it is often abundant. The best specimens come from the white limy cherts and the beauty and perfection of many of these are beyond description and can be appreciated only by being seen.

This blastoid varies quite a great deal in the character of the ornamentation, size, shape and in the size of its basal plates and in the depth of the basal concavity. In some specimens, notably the typical Melo, the ambulacra are sunk deeply between the radial lips and the deep interradial sutures give the specimens a truly melon shape. In other specimens the ambulacra are scarcely below the level of the radial boundaries. The variety with a large flat base approaches Cryptoblastus projectus.

The disposition of the granular ornamentation to pass from hardly noticeable lines of granules to fascicles gives rise to many elegant shapes.

A very rare variety is constricted at the top of the radials or fork pieces and again at an equal distance above the base, giving an appearance not unlike that of a beer keg. While in most of the specimens the interradials or deltoids stand out strong above, one very queer variety has the radials or fork pieces very prominent at their upper extremities and the deltoids much below them and tucked in at the central opening. This same variety has a broad, flat base. The strong lines of granules are conspicuous on Cryptoblastus concinnulus, probably only a variety of Melo. One well marked variety has very small granules, shallow ambulacra and an almost circular outline in a cross section.

The statement that the young of granatocrinoid blastoids are elongate while the adults are globose will hardly hold, as an extensive collection of any Burlington species will show. An undescribed species, associated with Melo and its varieties in the 3rd division of the Lower Burlington, is elongate with minute granules and having the ambulacra level with the top of the radial lips and is midway between Melo and Pisum. Cryptoblastus projectus is probably nothing more than a strongly marked variety of Melo, although the ornamentation is much finer.

In spite of the fact the deltoids in Melo are small, yet in several of the varieties they are conspicuous even in their smallness, as they take on a warty appearance and are horn-like at the upper part and in strong contrast to the previously mentioned variety, in which the deltoids are depressed and much below the level of the upper end of the fork pieces.

Next to Melo, Schizoblastus sayi is the most common Burlington blastoid and is found plentifully in its zone. It ranges from the very base of the Upper Burlington to near the middle of that formation, being most abundant below. Most of the variation in this species is in the ornamentation. The shape is more or less round even in the young, although elongate specimens are not rare, neither are they confined to the young.

A large variety occurs near Curryville, ornamented by festoons of node-like granules almost large enough to be called warts. The cherts at the base of the Upper Burlington are rich in natural casts of the inside of this blastoid. The writer has found a single undersize specimen of S. sayi at the top of the Lower Burlington.

Fully half of the specimens of S. sayi have the central opening above arched over by a covering of minute pieces, continuing for a little way over the ambulacra. One specimen has the anal opening at the top of a short proboscis, composed of small pieces. This can hardly be an abnormal feature and a suspicion, long present in the writer's mind, that two other Burlington blastoids possessed in life short anal probosces, is here strengthened.

In order of importance, Granatocrinus or Orbitremites norwoodi comes next.

In the cherts near Curryville this fossil is far more abundant than Schizoblastus sayi, but the reverse is the condition at Louisiana. The chief character of this species is its deep basal concavity. It varies both in size and ornamentation, but less so in the latter respect than Melo. A single rotund specimen was taken from the top of the Lower Burlington limestone at White Ledge, Mo., probably G. norwoodi var. fimbriatus.

At Louisiana it occurs near the top of the Upper Burlington above the S. sayi horizon.

The beautiful internal casts of this blastoid are a perfect delight to the chert breaker.

From a Spencer Creek flint, hardly two feet square and nine inches thick, the writer obtained twelve perfect casts and destroyed half as many more.

Pentremites elongatus ranges throughout the Upper Burlington but is always rare. It occurs in southwest Missouri

more abundantly than anywhere else in the state. A very large chert cast has an extra piece in the anal area, a small diamond shaped plate, resting in a triangle made by the upper outer edges of the radials and extending upward as an elongate triangle along the middle of the anal interradial.

P. burlingtonensis does not occur at Louisiana and its genuineness as a distinct species is doubtful. It is probably a rotund P. elongatus.

Granatocrinus? pisum accompanies C. melo throughout its range but is never abundant. Its chief characters are its concave interambulacral areas, narrow, prominent ambulacra, width of the basal region and minuteness of the granular ornamentation. The chief departure from the above specific characters is the rotund variety wherein the interambulacral areas are flat or convex. Granatocrinus exiguus is probably nothing more than a strongly marked variety of G. pisum. It occurs at Louisiana from the base of the Lower Burlington to the top of the 4th division and is a very handsome species. Codonites? inopinatus occurs very sparingly throughout the 1st, 2nd, 3rd and 4th divisions of the Lower Burlington and may be readily recognized by its strong linear ornamentation, very convex base, the interambulacral elevations at the top of the fork pieces and the sharply elevated margins of the anal opening, suggesting the probable possession of a short proboscis. It is our handsomest species and one of the rarest forms at Louisiana.

Granatocrinus aplatus is found in the top of the 5th and throughout the 6th horizons of the Lower Burlington, but most plentiful in the earthy layer between these two horizons. Its conspicuous characters are its flat base, strong toothed ornamentation, prominent elevation of the anal interradial about the anal opening and its elliptical spiracles. The posterior spiracles of this species are not confluent with the anal opening as originally supposed. One variety of this species simply has linear ornamentation while another is elongate and differs much from the typical form, which is almost round.

This species is congeneric with Codonites? inopinatus and probably G.? neglectus, which is not recognized among our forms. Aplatus varies in size from specimens scarcely larger than a radish seed to those as big as a medium size pea. It probably had a short anal proboscis.

Granatocrinus? magnibasis is a rare species, confined to a horizon less than a foot in thickness at the very base of the Upper Burlington limestone. It is easily known by its concave summit, very large convex base, narrow elevated ambulacra, small deltoids and wrinkled character of ornamentation. Internal chert casts of this species have extravagantly elevated ambulacral ridges.

Associated with Magnibasis is Granatocrinus calycinus, a very small blastoid with flat or slightly concave base, fine granular ornamentation and rather wide prominent ambulacra. It resembles G. pisum from the Lower Burlington, in outline only, as it has much larger deltoids, broader ambulacra and is a much smaller form.

Granatocrinus pyriformis is from White Ledge, Mo., but is specifically near to G. magnibasis.

Of all the Burlington blastoids, Granatocrinus stella is the rarest and most peculiar. It is associated with G. calycinus and G. magnibasis and may be known by its strongly stellate form. Natural casts of this species from chert are almost discoidal in outline. Like G. magnibasis, with which it is congeneric, it has a concave summit, large convex base and a linear ornamentation.

From the top of the Upper Burlington chert come two casts, one of which may be Granatocrinus excavatus with deltoids fully as long as fork pieces, granular ornamentation and concave base. The other is a small elongate form with large deltoids and slightly concave base, probably a new species, congeneric with S. sayi. Granatocrinus melanoides and G. shumardi are not recognized among our blastoids.

Codonites whitei is very rare and from the bottom of the 4th or top of 3rd Lower Burlington horizon. From the same strata comes Codaster gracillimus, a rare form, recognizable by the short, narrow ambulacra, confined to the summit. The largest and most desirable blastoid from the Burlington is Codonites or Orophocrinus stelliformis, which ranges from the bottom to the top of the 4th Lower Burlington horizon but is never common, having its greatest development near the top of that bed and associated with Cryptoblastus melo On old specimens of this species the linear ornamentation becomes cordlike, and the underside of an ambulacral ray

(fork piece or radial) reminds one of a rugose coral. The young examples of stelliformis are more elongate and less lobed than the larger specimens, but cannot be confounded with C. whitei.

Codaster grandis is a rare form and mimics the granatocrinoids in shape. Its narrow, elongate ambulacra confined to the summit, the numerous exposed hydrospire slits, thin test and linear ornamentation are characters by which this peculiar blastoid may be readily recognized. It comes from the very base of the Upper Burlington, associated with G. magnibasis. G. stella and G. calycinus.

Codaster? læviculus comes from the same bed and is more abundant than its associates. It may be recognized by its obconical shape and short, broad sunken ambulacra. This blastoid seems to belong to a genus other than Codaster and presents characters that ally it with both Phænoschisma and Cryptoschisma.

Metablastus lineatus is rare at Louisiana, but apparently ranges through both Burlingtons. A natural cast from Upper Burlington chert, in the writer's collection, is a veritable giant, being much larger than M. wortheni of the Keokuk. Specimens from the Lower Burlington are much smaller.

Owing to the close relationship between the Chouteau and Lower Burlington faunæ, it might not be greatly out of place here to review the blastoids of the Missouri Chouteau. The earliest described species is Granatocrinus roemeri from the lower beds. It occurs not rarely in southwestern Missouri and even as far north as Providence.

Its globose shape, strong granulo-linear ornamentation and flat base will readily distinguish this species. G. sampsoni is a synonym for G. roemeri. It, however, probably comes from the Upper Chouteau. There is not so much variation in the ornamentation of this species as in C. melo but there is a strong resemblance in outline among some of the varieties of these two species. Roemeri is, however, not congeneric with C. melo.

Granatocrinus mutabilis comes from the top beds of the Chouteau near Bowling Green and Curryville. It is a very changeable species, the young of which have strongly convex bases, while the adult specimens have either flat or slightly

concave bases. This blastoid has its nearest ally in G. pisum

Codaster blairi comes from beds near Sedalia and the writer knows it only from Mr. Miller's description.

An undescribed Codaster-like blastoid, found near Sedalia, is in Mr. R. A. Blair's possession.

A Classified List of the Blastoids from the Burlington Limestone at Louisiana, Missouri.

Pentremites	elongatus	Schizoblastus	sayi
Cryptoblastus	melo	"	sp?
"	projectus	Granatocrinus	norwoodi
"	concinnulus	"	excavatus
"	sp?	"	exiguus
Granatocrinus	calycinus	Codaster	gracillimus
"	? magnibasis	"	grandis
"	? stella	"	læviculus
Codonites	stelliformis	Metablastus	lineatus
"	whitei		
"	? inopinatus		
"	? aplatus		

Within the past week and since the above list was made out, the writer has found a single specimen of Codonites at the top of the fifth division of the Lower Burlington. It seems to be specifically identical with Wachsmuth & Springer's Kinderhook blastoid, Orophocrinus conicus.

Remarks.

In his description of Cactocrinus obesus, Mr. Keyes merely gives the horizon as Burlington limestone, as the type specimen came to him among a number of unlabeled crinoids from both divisions of the Burlington. In fact, this species is not only from the Upper Burlington, but from the middle of that horizon, associated with Physetocrinus ventricosus, Strotocrinus regalis and Agaricocrinus bellatrema. Messrs. Wachsmuth & Springer, in their great work on the Palæocrinoids, give the horizon of C. obesus as Lower Burlington and follow Mr. Keyes in giving the locality as Hannibal. The types were collected at White Ledge by a quarryman named Arnold. Then, Messrs. W. &. S.'s statement that Cactocrinus glans is the only species of the genus to survive the Lower Burlington is incorrect.

Mr. Keyes' Eretmocrinus expansus, despite its inflated ventral side, is a Cactocrinus. The second primary radial plate is hexagonal and it wants the expanded basal plates.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Glacial Erosion in the Valley of the Ticino. By W. M. DAVIS. Appalachia, vol. ix, pp. 136-156, with six figures in the text and two plates (views photographed); March. 1900.

On the south side of the Alps, the formerly glaciated Ticino valley is cut steeply down 200 to 400 meters below the lower margin of gentle upper slopes at each side, upon which the peasants have their summer villages, with hayfields and pastures. The gently ascending upper tracts are regarded as continuations of the original or preglacial valley floor, into which glacial erosion, more powerful because performed by deeper and faster flowing ice than at the sides, channeled the present precipitous inner valley. The courses of tributaries of the Ticino, on the gently inclined hights, before coming to the deep trough of glacial erosion, are called "hanging valleys" by Davis, adopting this term from Gilbert's studies, soon to be published, of Alaskan fjords and their similarly related tributaries. The same conditions also had been pointed out several years ago, by Prof. R. S. Tarr, in the case of Cayuga lake and others of the Finger lakes of central New York. It is thence inferred that glacial erosion generally, as by the entire North American ice-sheet, was more effective in determining the present topography of the country, its valleys and fjords, lake basins, etc., than has been before supposed by the author and by many other glacialists. W. U.

The Geography of the Region about Devil's Lake and the Dalles of the Wisconsin, with Notes on its Surface Geology. By R. D. SALISBURY and W. W. ATWOOD. Wisconsin Geological and Natural History Survey. Bull. V. Educational Series I. 150 pages, 38 plates, 47 figures, 1899.

This volume is intended for use in schools, and its plan is to treat fully and in an elementary way all general questions suggested by the details of the region. The Devil's Lake region is admirably suited to this purpose as it contains structural, topographic and glacial problems. Its striking scenery renders it of still greater interest and makes possible the most desirable of educational media—good illustrations. Mr. Atwood's photographs and sketches are admirable, both artistically and geologically, and invariably illustrate the points which they are intended to explain.

In Part I the topography and surface geology are considered. The two Baraboo quartzyte ranges rise above an undulating plain. The ranges are of Upper Huronian age, highly metamorphic, and in some localities schistose. Resting unconformably upon this formation and forming the country rock of the plain are horizontal beds of Potsdam sandstone and of Lower Magnesian limestone. The topography is of two types—glacial and erosion.

Part II treats of the history of the topography. The Baraboo region is treated as an example of the results of processes of rock formation of rain and river erosion, and of glaciation. The work is not so much a description of the region as a general treatise on a few of the processes involved in the evolution of land surfaces. Erosion is treated in an original manner and this portion of the work should prove of value to teachers indicating the true method of beginning any science. It treats of rivers from their origin and traces their development, thereby departing from the usual text-book method of discussing and classifying completed geographic forms. The portion devoted to the glacial period is probably the best treatment of the subject accessible to those who are not geologists and the Baraboo region affords an admirable field for the discussion of glacial phenomena.

The form of the paper is such as to render its paramount value educational rather than geological. The most evident original work is contained in a masterly treatment of simple and familiar processes rather than in the solution of the Devil's lake problems. Yet these problems are important in themselves and the paper might have gained in usefulness as a work of geology without a lessening of its educational value by placing more emphasis on the local phenomena themselves, by a less elementary treatment, particularly in the portion on rock formation.

I. H. O.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Bain, H. F., (S. Calvin and)

Geology of Dubuque county. (Ann. Rep. Geol. Sur. Iowa, vol. 10, 1899, pp. 385-651.)

Barbour, Carrie A.

Report on the Morrill geological expeditions of the University of Nebraska. (Science, vol. 11, new ser., p. 856, June, 1900.)

Barrows, D. P.

The Colorado desert. (Nat. Geog. Mag. vol. 11, pp. 337-351. Sep. 1900.)

Bishop, Irving P.

Petroleum and natural gas in western New York. (17th Ann. Rep., State Geologist of New York, pp. 11-63. 1899.)

Bownocker, J. A.

The paleontology and stratigraphy of the Corniferous rocks of Ohio. (Bull. Sci. Lab. Den. Univ., vol. 11, pp. 11-40. 7 plates. May, 1898.)

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology, and mineralogy.

Calvin, Samuel (and H. F. Bain)

Geology of Dubuque county. (Ann. Rep. Geol. Sur. Iowa, vol. 10, 1899. pp. 385-651.)

Chamberlin, T. C.

On the habitat of the early vertebrates. (Jour. Geol., vol. 8, July-Aug., 1900, pp. 400-412.)

Collie, Geo. L.

The gross topography of the globe. (Bull. Am. Bureau of Geography, vol. 1, pp. 8, 1900.)

Collie, Geo. L.

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Stratigraphic geology of the eastern Helderbergs. (17th Ann. Rep., State Geologist, N. Y., pp. 330-354, plates. 1899.)

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Geology of Worth county. (Geol. Sur. Iowa, vol. 10, pp. 317-377. Ann. Rep. 1899.)

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Mineralogical and petrographic study of the gabbroid rocks of Minnesota, and more particularly of the plagioclasytes (I). (Am. Geol., vol. 26, pp. 151-188, plates 8-19, Sept. 1900.)

CORRESPONDENCE.

REMAINS OF THE MAMMOTH IN ARIZONA. The upper jaw and teeth of a mammoth, presumably *Elephas americanus*, were recently exhumed from the ancient alluvions of the Colorado river at Yuma, Arizona. One of the lower molars together with fragments of the tusks were also found. The alveoli of the tusks are about seven inches in diameter. Other bones were broken up and lost before the relics were brought to the notice of Mr. Herbert Brown, who sent them to the museum of the University of Arizona at Tucson.

This discovery is interesting, showing the former presence of the mammoth in Arizona; extending knowledge of its range on the Pacific slope and in connection with the discovery of remains of the mastodon* and of the giant bos or bison,† indicating former conditions of greater precipitation, moisture and vegetation in that region, now noted for its aridity. WM. P. BLAKE.

University of Arizona, Tucson, June, 1900.

DR. ANGELO HEILPRIN AND THE DECREASE OF WATER IN LAKE NICARAGUA.—Dr. Angelo Heilprin has published two or three papers recently—the most recent in the "Supplement to the Scientific American"—in which he declares that the supply of water in lake Nicaragua "is from some unaccountable cause rapidly decreasing." Between 1880 and 1890 he declares that the decrease has been more than 20 feet, and refers, as data for his statement, to reports of engineers made, some a century ago, to the reports by Mr. A. P. Davis, hydrographic engineer to the Interoceanic Canal Commission.

The facts in the case are: There never was a reliable instrumental survey made and revised for corrections or confirmations until that made in 1898-99 by Mr. A. P. Davis or his corps of hydrographic engineers.

In this report they do not declare that there is any decline in the water level in lake Nicaragua between 1880 and 1898, nor earlier nor later.

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*AMERICAN GEOLOGIST.
†AMERICAN GEOLOGIST.

The hydrographic engineers have endeavored to note accurately during 1877-99 the inflow, outflow and loss by evaporation of both lakes Managua and Nicaragua connected by the Tipitapa river. At times there were unfortunately some careless men in employ of the Interoceanic Canal Commission, hydrographic division, until Mr. A. P. Davis discharged them as soon as he discovered their inefficiency.

The aqueous condensation is not represented in full by the rainfall. This aqueous condensation other than the rainfall is affected by variations in temperature the same as is the evaporation: evaporation is caused by currents of dry winds and the heat during the day, whereas the fall in temperature of several degrees during the night causes the condensation of the aqueous vapors from the oceans to a quantity worth estimating.

If between 1880 and 1898, there has been a decline of 20 feet from the 1880 level of lake Nicaragua from any cause, then the beach marks of the 1880 level would be easily found along the borders of the lake. But there is no such evidence to be found.

There is no question of the fact that the entire American isthmus from Salinas bay in Mexico to the south side of Darien is subsiding slowly; while south of Darien on the Pacific ocean side at least to the straits of Magellan there is a corresponding elevation of the land, but much too small annually to be generally noted. Should this subsiding of Nicaragua continue, the time will come centuries from now when the Nicaragua canal route that Prof. A. Heilprin seems to be after will require only a very short cut or channel, if any, to connect the waters of the Atlantic and Pacific oceans. There was a time evidenced by the fjords on the eastern coast of Nicaragua, southern and southwestern Cuba and western sides of the Antilles, when Nicaragua was a continent extending eastwardly to at least the east side of the Antilles. Now Nicaragua and the entire American isthmus is sinking as above stated.

Comparing the "rainy season" —thus far —of 1900 with previous seasons we are likely to have as much water in lakes Nicaragua and Managa in November and December, 1900 and January, 1901 as there was in 1880, which has been reported I am not certain but 1878 or 1880— as a year when because of excessive rains, and consequently also a reduced temperature and less evaporation, the water in both lake Managua and in lake Nicaragua, discharging the surplus through Rio Tipatupa into the latter—were 7 to 10 feet higher than ever noted in history before. The rainfall in July, 1900 has been excessive, twenty-one torrential rains and two all-night rains in western Nicaragua; and this excessive rainfall continues to date, August 14, 1900.

J. CRAWFORD.

PERSONAL AND SCIENTIFIC NEWS.

Dr. T. C. Hopkins has been appointed to the chair of geology at Syracuse University.

A Successor to Prof. J. M. Safford, at Vanderbilt University, has been elected by the selection of Prof. L. C. Glenn, of South Carolina college.

Mr. J. E. Spurr of the U. S. Geological Survey, returned to Washington, D. C. September 29th, from an examination of the Monte Cristo mining diftrict in the Cascade mountains, Washington.

Prof. Richard E. Dodge has spent the summer continuing the geological study of the region inhabited by the cliff dwellers in Arizona which he began a year ago for the Hyde Exploring Expedition in connection with the American Museum of Natural History.

Mr. Russell D. George has been appointed instructor in geology in the State University of Iowa, having charge of the work in mineralogy aad petrology. Mr. George has been a graduate student in geology at McMaster University and at the University of Chicago. At the latter institution he was fellow in geology and later assistant in mineralogy and petrology.

The Tiffany Exhibit of American Gems and gem material at the Paris Exposition, which was gotten together and arranged under the direction of George F. Kunz, has received the highest commendation from the authorities of the exposition and from visitors. After the close of the exposition it is to be installed in the American Museum of Natural History as the gift of one of the trustees.

Prof. J. J. Stevenson spent the summer in Europe with his family. He attended the meeting of the International Congress and made some special studies of the coal beds of France. Prof. J. F. Kemp spent most of the vacation in an extended private geological investigatton in British Columbia. Prof. R. P. Whitfield has returned to his regular duties at the American Museum of Natural History after a prolonged absence on account of sickness. His health seems to be completely restored. Dr. W. D. Matthew has returned from Europe, where he has been spending about four months in visiting and studying in the principal museums and in attending the International Geological Congress.

According to Prof. O. C. S. Carter, who recently visited the park of silicified trees in Arizona, the tree trunks are fossilized in a stratum of sandstone, probably of Cretaceous age, the Shinarump formation of Powell. The trees are all fallen, thus differing from the erect trees found silicified in the Yel-

lowstone park, which are in Tertiary rocks. Mr. Geo. F. Kunz reported silicified trees near Carrizo, Arizona, projecting from volcanic ashes and lava, covered by sandstone to the depth of 20 or 30 feet. The species prevalent in Arizona belong to the genus Araucaria, which has representatives in the south Pacific ocean which grow to the hight of 150 to 200 feet. Some specimens, however, resemble red cedar. All specimens show that the wood was undergoing decay before being petrified. On some specimens traces of fungi causing decay were found. These facts indicate a mild climate when the trees grew. The erect trees in the Yellowstone park belong to the genus Cupressinoxylon. Some trunks rise only a few inches above the ground. Some are Sequoia. The largest trunk in the park is ten feet in diameter, and the highest trunk standing does not exceed 30 feet high. They are found near Lamar river, the finest exhibit being on Amethyst mount, and Specimen ridge, near the road between Mammoth hot springs and the town of Cooke, Montana. Yancey's fossil forest is one mile south of his hotel on the slope of a hill 1,000 feet above the valley. There are only two trees of considerable size, the largest stump being 15 feet high and 13 feet in circumference. The bark is not preserved, so that the true diameter cannot be ascertained. Recently 25 specimens of petrified wood were found at Three Tuns, Pennsylvania, in a disintegrating sandstone with a feldspathic cement overlying the new red sandstone.

"The most prominent theory to account for the petrifaction of these trees is that the trees in situ were buried by a cinder shower from an active volcano somewhat after the manner that Herculaneum and Pompeii were buried by ashes from Vesuvius. Showers of rain generally accompany volcanic eruptions and the finely divided cinders were swept down the slopes in the form a volcanic mud, which is called tufa when hardened. The tufa and cinders, it is supposed, covered the trees entirely. Afterwards hot alkaline waters passing through the tufa and cinders dissolved out the silica, and when this water came in contact with the trees petrifaction began, each particle of woody matter being replaced by silica until the replacement was complete and the petrifaction finished."

Silica in solution in alkaline water, whether rain water or oceanic water, readily replaces organic tissues, and other noncrystalline substances such as volcanic glass, or obsidian, and appears to be the prime agent in the production of many apobsidians.

THE

AMERICAN GEOLOGIST.

VOL. XXVI. NOVEMBER, 1900. No. 5

MINERALOGICAL AND PETROGRAPHIC STUDY OF THE GABBROID ROCKS OF MINNESOTA, AND MORE PARTICULARLY, OF THE PLAGIOCLASYTES.

[Continued. See plates in the September and October Numbers.]

By ALEXANDER N. WINCHELL, Butte, Mont.

CHAPTER IV (Continued). Plagioclasyte.

Chemical Compositon of Labradorite. The analysis was made on pieces carefully selected, several having served for goniometric measures. All the fragments floated in a liquid of the density 2.709 and sank in one of the density 2.696; the average density of glass clear grains was 2.701; the whole was then carefully examined with the microscope and all impure grains mechanically removed. But in the final powder used some traces of hematite still remained. The main analysis was executed by the Deville method; the alkalies were determined by the Lawrence Smith method.

The composition of the labradorite studied is therefore very nearly Ab_3An_4; the analysis indicates that it is a trifle more basic than this, but the differences are wholly negligible. In specific gravity the mineral is a shade lighter than the theoretical compound. The iron oxide is present in the form of hematite very finely divided, so that the iron is in the form of the sesquioxide; only a trace at most of ferrous iron is present. The composition of the mineral is nearly the same as that of the rock. (See plate XIII, figures 7 and 11).

The analysis furnished the values in the first column below; a series of similar analyses is added for comparison:

	1	2	3	4	5	6	7	8	9	10	11
SiO_2.	53.38	51.30	54.47	55.59	54.20	53.56	54.00	56.18	54.55	51.89	53.7
Al_2O_3	29.70	31.46	26.45	25.41	29.10	27.78	27.82	27.33	28.68	29.68	29.6
Fe_2O_3	.21	....	1.30	2.73	1.10	1.15	....	1.38	1.03	.32	....
FeO	....	....	.67	....	....	....	1.50	....	....	.37	....
MgO.	Trace	.69	....	....	.15	Trace	.05	....	....	.38	....
CaO	11.90	12.20	10.86	11.40	11.25	12.01	11.20	10.33	11.23	12.62	11.8
Na_2O	4.30	5.53	4.37	4.83	3.80	4.10	4.76	5.17	4.62	3.87	4.9
K_2O	.56	.79	.92	1.32	....	1.68	.43	.36	.42	.50	....
H_2O	.37	....	.53	....	.40	....	....	....	....	.46	....
	100.42	101.08	100.20	100.28	100.09	100.28	100.04	100.75	100.53	100.09	100.00
Sp. Gr.	2.701	2.702	2.72		2.689			2.698	2.700	2.700	2.703

1. Labradorite separated from the plagioclasyte of Carlton peak, Minn. (analyzed by the author).

2. Labradorite from near Encampment island, Minn. (Analysis by W. C. Blasdale, Univ. Calif.; reported by A. C. Lawson: Geol. & Nat. Hist. Surv. of Minn. Bull. No. 8, p. 6.

3. Bluish opalescent labradorite from Mt. Marcy, New York. (A. R. Leeds: thirteenth Ann. Rep. N. Y. State Museum Natural History, 1876).

4. Labradorite from Paul's island, Labrador: (G. Tschermak in Rammelsberg's Mineralchemie).

5. Blue opalescent labradorite from plagioclasyte of Morin, Canada (T. S. Hunt: Geology of Canada, 1863).

6. Bluish-gray untwinned labradorite, Paul's island, Labrador. (G. Hawes: Proc. Nat. Museum, Washington, 1881.)

7. Labradorite, Paul's island, Labrador. With traces of MnO, SrO, and Li_2O; 19 lost on ignition. (Jannasch, Neues Jahrb. f. Min. 1884.)

8. Labradorite from Labrador, by C. Clement (Schuster, Mineral. u. Petrog. II. 43.) Mitth. Tschermak, Wien, 1880, III, p. 183.

9. Labradorite from Kamenoi Brod. Kiew, Russia, by Schuster. loc. cit., p. 184.

10. Labradorite from olivine gabbro, Sec. 35-61-12W., Minn. (Analysis by W. H. Hillebrand, U. S. Geol. Surv.; reported by W. S. Bayley, Jour. Geol. I, 701, 1893.

11. Theoretical composition of Ab_3An_4.

AUGITE. While pyroxene may be entirely lacking in some thin sections and is never abundant, it is, in small amount, a normal constituent of the plagioclasyte. It only rarely shows crystal outline, but the faces $m(1\bar{1}0)$, $g^1(010)$, and $h^1(100)$ have been noted. The pyroxenic cleavage is usually very distinct, and parting is often developed parallel to $h^1(100)$ as the augite

passes into diallage. Twinning occurs parallel to $h^1(100)$. The mineral is very dark green to black in mass, but in thin section it is colorless. In sections however, as thick as .1 mm a distinct pleochroism can be observed as follows:

$$n_g = \text{greenish}$$
$$n_m = \text{greenish yellow}$$
$$n_p = \text{pale greenish}$$

The absorption formula is $n_g = n_m > n_p$

The refringence is very high producing a marked relief and a shagreen surface; the latter also shows that the mineral possesses considerable hardness. The birefringence is about .022, and gives bright colors usually red or blue. The acute positive bisectrix is n_g about which the optic angle is large.

MAGNETITE. The iron oxide as a primary element of the rock is often even rarer than the augite. Good crystal outline is uncommon, but the mineral may be enclosed within either the augite or the labradorite. The octohedral parting parallel to the pyramidal crystal faces has been noted well developed. Magnetite occurs oftener as a decomposition product, in the form offine particles and masses, than as a primary mineral.

APATITE. This mineral is very rare in the plagioclasyte from Carlton peak. It shows sharply defined hexagonal crystals in which cleavage can sometimes be detected parallel to the base (0001), and more imperfectly parallel to one or more prismatic faces. In this rock it is strictly uniaxial and negative.

INCLUSIONS OF THE PRIMARY MINERALS. *In the labradorite.* As early as 1845, Sheerer * made a study of the inclusions in labradorite from Hitteröe, Norway, and reached the conclusion that they consisted of hematite, ilmenite, and one or two more undetermined minerals.

Vogelsang,† in 1868, studied the inclusions in labradorite from the coast of Labrador, but chiefly with reference to their possible connection with the play of colors seen on certain surfaces. He showed that they were practically unattacked after remaining four days in hot hydrochloric acid.

*T. Sheerer: Annalen der Physik und Chemie. Poggendorff. LXIV. 1845, p. 163.

†H. Vogelsang: Sur le labradorite coloré de la côte du Labrador. Archives Néerlandaises. II. 1868.

Schrauf,* in 1869, made a very careful and detailed study of the inclusions in labradorite from the coast of Labrador and from several points in Russia and distinguished:

First, Augite needles, usually numerous.

Second, "Microplakites," of unknown nature; they are perpendicular to the augite needles; usually square with sharply defined outlines; they are reddish, greenish or bluish in reflected light, and brownish in transmitted light; being dark between crossed nicols, but perhaps not monorefringent.

Third, "Microphyllites," of unknown nature; they lie parallel to the augite needles; and are roughly oblong without good outlines; they are gray brown, and monorefringent; and lie in the cleavage plane (180).

Hagge,† in 1871, studying rock from Labrador again, found that all the brown scales were dissolved in hydrochloric acid before the feldspar was attacked at all, and concluded that they were göthite.

Judd,‡ on the contrary, found that those in the gabbros of Scotland were insoluble in hydrochloric acid. He considered that the inclusions are composed of various hydrous oxides, such as opal, hyalite, limonite, göthite, and also "titanoferrite" and are not definite chemical compounds, but amorphous mixtures, and hence anisotropic. He asserted that they are all of secondary origin, due to the solvent action of water at great depths and under high pressure; in such circumstances the solvent power of the water is greatly increased and it acts along certain planes of strain; the inclusions are evidently not derived from the labradorite, but according to Judd from the accompanying augite. In short he considered them schillerization products.

Adams§ found similar inclusions in labradorite from Can-

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*Schrauf: Studien an der Mineralspecies: Labradorit: Sitzber. Akad. Wissensch. Wien. Bd. LX. (1) p. 996, Dec. 1869.

†Hagge: Mikroskopische Untersuchung über Gabbro und verwandte Gesteine. Kiel. 1871. p. 46. Cf. Adams: Neues Jahrb. f. Mineral., etc. Bd. VIII. p. 436.

‡Judd: On the gabbros, dolerites, and basalts of Teritary age in Scotland and Ireland; Quart. Jour. Geol. Soc. 1886. Cf. Judd. Quart. Jour. Geol. Soc. 1895. p. 354.

§F. D. Adams: Ueber das Norian oder Ober-Laurentian: Neues Jahrb. f. Miner., etc. Bd. VIII. 1893. p. 435.

ada, and especially from the Morin district. He decided that the "minute black rods" are ilmenite needles. He also found red brown scales resembling hematite, but probably also titanic iron oxide; and fluid inclusions arranged in rows, occasionally with movable bubles. All these inclusions disappear when the labradorite is granulated.

Bayley* found that the labradorite of the normal Minnesota gabbros usually contains the "characteristic acicular inclusions," though they are sometimes absent. He also mentions the presence of "dust-like particles scattered everywhere throughout the grain."

Lawson† studying the plagioclasytes of Minnesota found inclusions of three general kinds:

I. Original mineral inclusions arranged in plates or rods parallel to definite crystallographic planes.

II. Original dust-like inclusions arranged in irregularly curving planes without reference to the crystal structure.

III. Secondary inclusions of red iron oxide in minute specks arranged peripherally to the plagioclase, or along the cracks which occasionally traverse it.

He further concludes that the inclusions of the first class are augite needles and granules, which resemble very strikingly the products described by Judd as due to the process of schillerization, and yet are demonstrably original inclusions, and due to no such process.

A study of the inclusions in labradorite from Carlton peak shows that they agree most closely with those described by Lawson, as might be expected, since he studied the same rock.

However the "rods or plates" are entirely absent, and no inclusions occur arranged parallel to certain crystallographic planes. Lawson describes them from another locality (near Encampment Island); it is evident they are far from constant in Minnesota plagioclasyte. The original inclusions‡ which occur at Carlton peak may be classed as follows:

I. Gaseous inclusions are very rare; indeed the few oc-

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*W. S. Bayley: The basic massive rocks of the lake Superior region: Jour. Geol. I. 1893. p. 699.

†A. C. Lawson: The anorthosytes of the Minnesota coast of lake Superior: Geo & Nat. Hist. Survey Minn. Bull. No. 8. 1893. p. 8.

‡Secondary inclusions will be discussed under the heading "alterations" later.

currences noted are all of questionable character and may perhaps be composed instead of a liquid of low index of refraction.

II. Liquid inclusions.

1. Along curving planes. Liquid inclusions are not commonly found along planes of any sort, but when found thus they are abundant. Their size varies markedly even along a single plane; instead of disappearing abruptly, they become smaller and smaller, but at the same time more and more numerous, as one approaches the limit of the plane. Thus the total amount of liquid (or liquids) enclosed probably remains about the same. More frequently, they are invariably very small along a given plane. The smallest liquid inclusions are always spherical, but the larger ones, while generally roughly spherical, may vary to shapes the most irregular. Very rarely they show rectilinear outlines, which are doubtless impressed upon them by the enclosing feldspar. All, except the very smallest, commonly contain solid inclusions; the smaller ones contain only one or two, while the larger ones usually contain several, and may show as many as thirty or forty. These solid particles never show any arrangement in the liquid, though they seem to invariably adhere to the surface of the surrounding mineral. Occasionally the larger cavities of the feldspar contain two liquids, one inside of the other. And indeed it is easy to distinguish two liquids in different cavities, since the ordinary one gives a marked relief, while another, occurring much more rarely has an index of refraction nearly as high as that of the feldspar, and the relief is scarcely perceptible.

2. Throughout the feldspar. The liquid inclusions which are scattered broadcast throughout the feldspar are usually always of extremely small dimensions. More rarely they also occur of larger size; when small they are roughly spherical, but when they become larger they usually lose all regularity of shape; like those occurring along planes they often contain black solid inclusions, which, however, have never been observed in such numbers as in the larger inclusions along the planes; they are usually limited to one or two.

III. Solid inclusions.

1. Along curving planes. These inclusions have already been mentioned as occurring within the fluid inclusions. That is their ordinary habitat, but they occur also, though more

rarely, separated from the liquid inclusions, and directly surrounded by feldspar. They are so small that their nature is practically indeterminable; they are completely opaque, black, and of irregular outline, usually roughly spherical. They are probably magnetite particles. They are certainly not ilmenite, since the rock contains no trace of titanium.

2. Throughout the feldspar. These inclusions are entirely similar in appearance and occurrence to those found along curving planes. They are quite generally distributed, but also very sparsely. It is remarkable that these dust-like particles are nearly always surrounded by liquid inclusions. It is probable that the liquid particles in the magma, once in contact with a solid particle, adhered strongly to it.

For purposes of comparison sections were made of labradorite of various other localities, from samples kindly put at the writer's disposal by Prof. A. Lacroix. In sections of the well known iridescent labradorite from the island of Paul on the coast of Labrador, no augite needles occur, though it was from this locality that Schrauf described them. On the other hand needles of magnetite* probably titaniferous are abundant. They correspond exactly in position and relation to the other inclusions of the feldspar to the "augite needles† as described by Schrauf.

The inclusions called microplakites and microphyllites by Schrauf, and considered to be wholly, or in part, ilmenite by Sheerer, Rosenbusch and Adams, occur in just the position assigned them by Schrauf. Minute particles of magnetite similar to those described from Carlton peak, also occur, but they are very rare. Liquid inclusions are abundant, especially along curved planes.

Sections from the plagioclasyte from Kiew, Russia, another locality studied by Schrauf, and described as essentially similar to the former, show the same titaniferous magnetite needles with a total absence of augite needles. The colored ilmenite microlitic tablets are abundant here also, but are not as characteristically developed. Here the feldspar shows the

*It will be shown that needles wholly similar sometimes mass themselves to form crystals readily determinable in the gabbros of Minnesota and notably in olivine diabase from Birch lake.

† Augite needles have been found in labradorite from Norway. See Lacroix:—Gneiss à pyroxene. Paris 1889. p. 145.

well known play of colors, though not as beautifully as that from Labrador. Black particles supposed to be magnetite are also abundant, while liquid inclusions are rare. These have not been seen along curving planes.

A section from the plagioclasyte of Lake Champlain, N. Y., shows an immense number of dust-like particles, probably magnetite, as well as liquid inclusions, both occur along lines and planes, and scattered everywhere through the mineral. They resemble in all essential characters those described from Carlton peak. No acicular inclusions are seen here, nor do the ilmenite tablets occur. The abundance of the magnetite particles gives the labradorite of this rock a deep black color but no iridescence is visible. Finally, sections from the Minnesota gabbros and diabases often show the black acicular needles, but they are never accompanied by iridescence.

As to the origin of these inclusions, it seems to the writer impossible to attribute them to the process of schillerization. or to any alteration process, since they occur in a feldspar often showing no evidence whatever of alteration of any kind. but perfectly fresh and glassy. They not unfrequently show crystal form peculiar to themselves and at variance with the forms of the enclosing mineral. Although liquid inclusions frequently exist in the mineral they are rarely bounded by negative crystal planes and have never been seen to contain the colored titanic tablets, as they should if they had developed through schillerization. But perhaps the most conclusive evidence that they are original and not secondary inclusions is afforded by the fact that there is often no mineral in sufficient quantity from which they could have been derived. Prof. Judd would have us believe that they were derived from the pyroxenic element of the rock, but that mineral is not uncommonly manifestly in far too small amount to furnish the myriads of inclusions which Vogelsang has estimated to amount to from one to three per cent of the volume of the rock, and to number sometimes as many as one hundred million per cubic centimeter!

Furthermore in many large areas of plagioclasyte the small amount of augite which does occur is perfectly fresh, showing no evidences of alteration of any kind, while the labradorite may be crowded with these inclusions. In other oc-

currences where the augite is found to alter, it usually changes first to diallage and then to chlorite, with the accompanying separation of iron oxide, as will be described later.

From this study of the inclusions of labradorite and the review of other studies, it seems safe to conclude that:

1. While inclusions of various kinds are very common in labradorite, inclusions of no kind are constant.

2. The black acicular inclusions of various kinds which occur so frequently in plagioclasytes and gabbros have no relation with the iridescence sometimes exhibited by the feldspar, since they occur frequently when no play of colors can be seen.

3. These acicular inclusions are composed of magnetite, probably titaniferous, in the vast majority of cases.

4. The magnetite needles are, in general, primary inclusions, though they are often accompanied by magnetite undoubtedly secondary in origin.

5. The peculiar rectangular scales called microphyllites and microplakites by Schrauf, are the sole and efficient cause of the play of colors, since the colors are never seen without the microlites, and the latter never occur without producing the colors.

6. The microphyllites and microplakites (probably ilmenite) of the labradorites studied here do not owe their origin to the process of schillerization as described by Judd, nor to any process of alteration, but are true primary inclusions.

Inclusions in the other primary minerals. No inclusions of primary origin have been seen in the augite or magnetite; the inclusions which from their color in reflected light have given name to bronzite, and which occur quite abundantly in the pyroxene of certain other gabbro rocks to be studied, are entirely absent in the plagioclasytes.

Neither have inclusions of indisputable primary character been found in the apatite, although a few liquid inclusions and several particles resembling magnetite have been observed which are essentially like those described in the feldspar. This is, however, in apatite, which in spite of its stable characters shows marked evidence of decomposition.

Alteration of the primary minerals. *Alteration of the labradorite.* There are three important methods of alteration to be distinguished:

I. The first method of alteration commences by an opening of the cleavage lines or a dissolving away of the material along cleavage lines; but this stage is often absent. It is only rarely, and then only in very small areas, that the transformed feldspar is carried away, and the empty cleavage left; usually the material remains in place as some zeolite of fibrous habit.

Next very fine particles appear which are opaque and black by transmitted light, and red by reflected light; they are doubtless hematite. As long as these changes are limited in amount they are also limited strictly to the cleavage lines, but when the transformation proceeds further the zeolite material begins to spread roughly at right angles to the cleavages, first sending out numerous narrow branches which soon connect the long cleavage lines by many perpendicular cross lines. thus forming an irregular quadrillage. The irregularity consists mainly in the fact that while one system of lines parallel to the cleavages is straight and continuous, the other system perpendicular to the cleavages is made up of lines very discontinuous, the same line only rarely crossing a cleavage line; at the same time these lines vary occasionally from the perpendicular and may even be curved. Hematite particles are rare along these lines.

After this stage the zeolitic material spreads in a manner wholly irregular and thus forms masses of shapeless outline—patches scattered through the feldspar. At the same time the hematite becomes more abundant and forms little masses no longer limited to the cleavages, but occurring indiscriminately here and there.

This method of alteration has never been observed to reach its fullest completion, and transform large areas of feldspar into zeolites, without the presence of the second method working at the same time.

II. The latter is much more rapid and irregular in its development; it follows no crystallographic directions, but occurs along the fracture lines which are always common in altered areas—doubtless because alteration has been much facilitated by the presence of these fractures and has thus developed itself with especial ease wherever they were present. The fractures are sometimes accompanied by a very slight change in extinction in various parts. This method of altera-

tion differs from the first. also, in producing more varied results; indeed, while the first ordinarily only gives rise to colorless zeolites and hematite, this produces zeolites of various shades, including scolecite, mesolite and pseudomesolite* tinted by hematite, clinochlore and penninite, and more rarely magnetite; it may also give rise to calcite, zoisite, and recrystallized fine granular or spherulitic labradorite.† Often parts of the original large mass of feldspar still remain wholly unaltered, while beside them can be found the neogenetic crystals frequently lath-shaped and of varying orientation. All about will be found: calcite, zeolites, chlorites, iron oxides, and occasional grains of zoisite. Careful search for epidote, garnet, quartz, an acid feldspar, and amphiboles, all common products of saussuritization, has been in vain.

This method of alteration shows no distinct stages of development, though it may be divided roughly as follows:

1. Appearance of fracture planes. This stage is only rarely observed since it is quickly followed by the next.
2. Development of zeolites and hematite along the fracture planes.
3. Development of other minerals.

III. There is still an other method of alteration which is illustrated in plate X, Fig. 2. While in the methods described heretofore the alteration begins on the outside and works inward along cleavages or fracture lines, in this case the formation of new minerals begins within and works outward. To distinguish more briefly between the two modes of alteration which are not confined to labradorite, nor to the feldspars, but occur commonly with many minerals, I would propose that the former be termed exogenesis, (or exogenetic alteration) and the latter endogenesis. Thus the method by which chlorite is ordinarily formed from hornblende is exogenesis; endogenesis is naturally much more uncommon. It is illustrated by the alteration of the feldspar just described, and by the formation of göthite at the expense of olivine. In this latter case, however, as well as in many others, the two methods of

*This is a new zeolite which will be described in detail later.

†It is possible that this may be in part albite, but it has been impossible to demonstrate the presence of the acid plagioclase.

alteration often work simultaneously and produce identical results.*

This third method, beginning anywhere within, instead of propagating itself along the cleavages or fractures, develops outward in all directions, but not with equal speed; it develops at once into a rude square or oblong, limited by the cleavages $p(001)$ and $g^1(010)$. This is of course best seen in sections which are cut perpendicular to $p(001)$ and $g^1(010)$. Hence a feldspar altering in this way shows many roughly rectangular, square or oblong areas wholly transformed to zeolites with some accompanying formation of iron oxides, chiefly hematite, scattered about irregularly, but with their sides always parallel, in the midst of the clear unaltered feldspar. If elongated, the elongation is nearly always parallel to the easy cleavage $p(001)$.

These various decomposition processes considered in another light and named from end products would be called chloritization, calcification, saussuritization, and zeolitization.

The alteration of the augite which is quite common, takes place in only a single way. It is often preceded by the appearance of the diallagic parting which develops first along the periphery of the grains and progresses inward. At the same time iron oxides, especially hematite, appear. The diallage often alters to chlorite, usually clinochlore.† The augite has not been seen by the writer, altering to hornblende, though

*There is another method of alteration which has not been observed in the plagioclasytes, but which has been described already. It consists in the development of "reaction products," that is, an alteration of two minerals simultaneously, taking place between the two, and usually resulting in the formation of a single mineral containing elements derived from both the minerals transformed. Thus biotite is formed at the expense of magnetite and plagioclase. While this method of alteration begins on the outside and proceeds inward, like exogenesis, it differs radically from the latter in that it necessarily advances in both directions—away from both minerals, as well as towards both minerals. It can, therefore, never advance very far into either mineral, for such an advance would remove it too far from the source of certain of the elements necessary to the continuation of its growth. Therefore, to emphasize the fact that this alteration must always remain between two minerals, the process could appropriately be termed mesogenesis.

†This transformation of augite to diallage and then to chlorite was noted in all stages by Irving: See third annual report, United States Geological Survey, p. 102.

this mineral has been noted as occurring rarely by both Adams* and Lawson.†

The alteration of the magnetite is also very constant in method. The first stage is represented by a dull earthy black substance. This is believed to be merely the amorphous state of magnetite, sometimes called ocherous magnetite. Next the color in reflected light changes very markedly, becoming dull grayish white to yellowish white, with occasional silver white submetallic reflections. In spite of its color, it is still perfectly opaque; it has become crystalline again, however, as shown by its fibrous character. This stage is limonite or common hydrous iron oxide. At the same time minute particles sometimes appear having the characteristic brass-yellow metallic lustre by reflected light of pyrite. The black amorphous condition is usually found between the magnetite and limonite. The alteration seems to begin on the periphery and progresses irregularly inward; the final effect in all cases is a mass of limonite crossed in all directions by lines, perhaps representing irregular planes of the magnetite.

Alteration of apatite. The apatite, which is frequently wanting also shows the effect of decomposition. It is, however, a very stable mineral, and is not transformed into any other; instead of changing to other minerals the apatite is first traversed by a few large fractures connected by numberless very minute cracks; along both appear various inclusions probably introduced by the action of water; these are dust-like particles apparently of magnetite, minute drops of liquid, and flakes of hematite;‡ the effect of these foreign elements is to give the apatite the appearance of a mineral in the process of transformation.

SECONDARY MINERALS. The minerals formed by the alteration of the plagioclasyte include: calcite, penninite, clinochlore, mesolite, scolecite, pseudomesolite, magnetite, hematite, limonite, and pyrite.

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*F. D. Adams: Report on the geology of a portion of the Laurentian area: Geol. Surv. Canada. Ann. Rep. Vol. VIII. 1896. p. 99j.

†A. C. Lawson: The Anorthosytes of the Minnesota coast of lake Superior: Geol. & Nat. Hist. Surv. Minn. Bull. No. 8. 1893. p. 8.

‡An unknown mineral associated, and even included, within apatite will be described later; the association is supposed to be accidental, and is not constant.

Calcite. In highly altered areas calcite is often quite conspicuous among the decomposition products. It never shows crystal outline, occurring in patches wholly irregular.

Penninite occurs only rarely, the ordinary product of chloritization being clinochlore. The two chlorites can be distinguished in this rock only by the weaker birefringence of the penninite which usually gives the "ultra blue" color between crossed nicols.

Clinochlore is sometimes fibrous, but oftener lamellar. It has perfect cleavage parallel to the base $p(100)$ to which n_g is nearly perpendicular. The color in mass is grass green, in thin section pale green with weak pleochroism as follows:

n_g =pale greenish yellow
n_m=yellowish green
n_p = green.

The absorption formula is the following: $n_g < n_m < n_p$.

The birefringence is about .010, and is distinctly greater than that of labradorite.

Clinochlore occurs very often as an alteration product of the pyroxene, and more rarely of the labradorite.

Mesolite occurs quite commonly at Carlton peak, in a manner showing most clearly its direct derivation from the labradorite, according to the method previously described. Mesolite is always fibrous, and often radially arranged. It has not been found at the Minnesota locality in fibers large enough to permit any determinations; through the courtesy of Prof. Lacroix, a few acicular crystals collected by M. Gentil at Takdempt, Algeria, were examined. They are very rich in faces of the vertical zone, four occurring between $m(110)$ and $m'(1\bar{1}0)$ contiguous. A measure of the angle $mm'(110) \wedge (1\bar{1}0)$ from a crystal giving unusually distinct and excellent images from both these faces gave the following result:*

$$mm'\ (110) \wedge (1\bar{1}0) = 91^\circ\ 35'$$

The angle between $m(110)$ and another well developed face of the vertical zone was: $mx = 157^\circ\ 20'$.

Mesolite has two good cleavages parallel to $m(110)$; its

*M. Gentil found on crystals from the same locality mm' $(110) \wedge (1\bar{1}0) = 91^\circ\ 22'$: See Lacroix: Minéralogie de la France. II. p. 276.

hardness is about 5. The lustre is vitreous and bright when well crystallized. The birefringence is about .006. The mineral is biaxial and positive with a large optic angle. The dispersion is not noticeable. The elongation is positive or negative, since the optic plane is perpendicular to the elongation. Fibers lying in the plane of the thin section seem nearly monorefringent. The maximum extinction angle in sections parallel to the vertical axis is about 5° in the preparations studied.

The mineral is often rendered less transparent by a cloud-like, amorphous, grayish-white decomposition product. Mesolite is soluble in the acids leaving a residue of gelatinous silica. Microchemical reactions show the presence of alumina, calcium and sodium, the last relatively in small amount.

Scolecite whose derivation from the labradorite is just as clear as that of the mesolite is always fibrous, elongated parallel to the vertical axis. The fibers are usually radially grouped, or nearly parallel. The refringence is inferior to that of Canada balsam while the birefringence is markedly superior to that of labradorite and seems to be as high as .012. The extinction angle in sections parallel to the elongation exceeds 12°.

Scolecite often includes minute inclusions, of secondary origin like itself, of hematite, chlorites, etc. It is much less abundant at Carlton peak than mesolite.

Pseudomesolite is a new zeolite which is very similar, in chemical composition to mesolite, from which it differs, however, very distinctly in optical characters. Hence the name by which it is proposed to designate the mineral.

From its optical characters the mineral is referred to the monoclinic or more probably the triclinic system. Pseudomesolite is eminently fibrous, in very fine fibers radially arranged or occasionally interlaced. In the spherulitic masses microscopic short fibers occur rather uncommonly making various, but usually small, angles with the general direction of the other fibers. These radial aggregations are both microscopic and megascopic in size, and it was from a group of the latter that material was obtained for careful study and chemical analysis. Twinning is rare, indeed it has not yet been observed; parallel fibers are usually oriented alike. Pseudomesolite has two good cleavages very nearly at right angles,

which by analogy with mesolite will be considered $m(1\bar{1}0)$ and $t(110)$.

The hardness is 4.5 to 5.; single fibers are very fragile; masses are tough especially across the direction of the fibers. The specific gravity determined with tetrabromide of acetylene and the Westphal balance is 2.215. Pseudomesolite fuses easily (fusibility about 2.) with no appreciable change of volume to a white porcelain-like mass. In the tube it gives water.

The color of pure pseudomesolite in fibrous mass is porcelain white; separate fibers are transparent and colorless. But it is often colored in shades of pink, and more rarely green, in bands perpendicular to the elongation of the spherulitic masses. These bands alternate with bands nearly pure white. The pink bands are undoubtedly due to the presence of fine particles of hematite; the green bands haye a dissimilar origin and are supposed to be due to the presence of iron protoxide replacing some other element (Ca?) in the chemical composition.

The lustre is usually rather dull, subvitreous to pearly. In thin section the perfectly fresh unaltered part is very transparent and colorless; but the larger part is only translucent, being nearly amorphous, and then may be called cloudy white.

The refringence is very low, always inferior to labradorite; there is a total absence of relief. The birefringence is somewhat weaker than that of mesolite, and is comparable to that of apatite, but probably weaker. Pseudomesolite is biaxial and positive with a very small optic angle: n_m and n_p are therefore practically equal. The elongation of the fibers is always positive, while the extinction angle in sections parallel to the elongation reaches a maximum of at least 20°; it is sometimes near 0°. Therefore n_g is approximately parallel to the elongation; the position of the other two indices relative to the faces of the vertical zone cannot be stated; it is only known that the extinction in transverse sections is sensibly parallel with the diagonals of the squares or rhombs formed by the faces $t(110)$ and $m(1\bar{1}0)$. Such sections between crossed nicols show a poorly centered bisectrix, which is positive, but the birefringence (n_m-n_p) is so weak that even with the thickest sections the interference figure is indistinct.

Pseudomesolite is slowly but completely attacked by the acids leaving a residue of gelatinous silica. The microchemical reactions of Boricky and Behrens show an abundance of alumina, considerable calcium, and less sodium.

Inclusions are not common; particles of hematite occur in the form of particles and microscopic lamellæ. On alteration, pseudomesolite becomes translucent, instead of transparent, in thin section, and becomes filled with cloudy masses resembling those of altering acid feldspars. These cloudy masses seem to have lost their crystalline character, at least in large part.

The material for chemical analysis was carefully freed of all the other minerals of the rock. A large spherulitic mass of nearly pure zeolitic mineral was repeatedly tested and the elongation of the fibers was found over twenty times to be uniformly positive; therefore no mesolite was present in the mass. Only the white and pink bands were utilized, so that the iron found was undoubtedly foreign to the zeolite. In the first column below are given the results obtained; the others are the results of various calculations except the sixth, which gives the composition of gonnardite.

	I	II	III	IV	V	VI	VII	VIII
SiO_2	45.25	45.89	46.75	46.40	41.7	46.35	45.99	52.99
TiO_2	none							
Al_2O_3	25.69	26.06	29.49	26.30	28.4	26.27	26.11	30.38
Fe_2O_3	1.40							
MgO	trace							
CaO	9.75	9.89	9.70	9.50	9.7	10.00	9.91	11.41
Na_2O	4.24	4.30	5.37	5.44	6.3	4.89	4.79	4.97
K_2O	.47	.48						.55
H_2O	12.99	13.17	11.69	12.36	13.9	12.49	13.20	
	99.79	99.79	100.00	100.00	100.00	100.00	100.00	100.00
Sp. Gr.	2.219			2.2 to 2.4	2.246 to 2.26			

I. Pseudomesolite from the plagioclasyte of Carlton peak, Minn. Analysis by the method of Deville; water determined by the loss on ignition.

II. Analysis I, calculated after deduction of the iron.

III. Theoretical composition of $CaNaAl_2Si_3O_{10}+2.5H_2O$.

IV. Theoretical composition of Mesolite of the formula:
$(Na_2Al_2Si_3O_{10}+2H_2O)+2(CaAl_2Si_3O_{10}+3H_2O_{10})$ or My_1Sc_2
Mesotype Scolecite

V. Theoretical composition of the compound:
$3(Na_2Al_2Si_3O_{10}+2H_2O)+7(CaAl_2Si_3O_{10}+3H_2O)$ or My_3Sc_7

VI. Gonnardite from Gignat. Analysis by Pisani, corresponding to the formula:
$(Ca, Na_2)_2Al_2Si_3O_{15}+5.5H_2O$. See Lacroix: Minéralogie de la France II, p. 279, 1896.

VII. Column II, after adding the K_2O and Na_2O, calculated to the scale of 100.

VIII. Column II, after deducting the water, calculated* to the scale of 100.

The composition agrees almost exactly with that expressed by My_3Sc_7, and it is probable that it should be considered as an isomorphous compound. In this connection it is interesting to note that, while so far as known the optical properties of these minerals are not such as are characteristic of isomorphous series, a careful examination of the analyses already published will disclose a series nearly complete, from mesotype to scolecite.

Pseudomesolite may be readily distinguished from mesolite by the following characters:

First. Its optical orientation, n_g being nearly parallel to the elongation, which is therefore always positive (in mesolite n_m is nearly parallel to the elongation).

Second. Its very small optic angle.

Third. Its high maximum extinction angle of at least 20° in the zone of the vertical axis.

Fourth: Its weaker birefringence.

The chemical composition of pseudomesolite is distinctly different from that of gonnardite,† though the optical differentiation of the two minerals is somewhat difficult. The birefringence of pseudomesolite is, however, only about one-half of that of gonnardite, while the extinction angle in sections of the vertical zone reaches a maximum near 20° in pseudomesolite and is always 0°, or very near it, in gonnardite.

Pseudomesolite is not readily confused with any other zeolites; in exterior characters it somewhat resembles thomsonite,

*See Plate XIII, Figure 12.

†See Lacroix: Minéralogie de la France. II. 1896. p. 279.

mesotype, or natrolite, scolecite, and stilbite; it differs from the first in its birefringence which is very much weaker, the very small optic angle, the elongation of the fibers, always positive, and the maximum extinction angle in the zone of the vertical axis (0° in thomsonite); from the second in the very small optic angle, the weaker birefringence, the maximum extinction angle in the vertical zone (0° in mesotype), and in the presence of calcium in notable amount.

Pseudomesolite is distinguished from scolecite* by the sign of the acute bisectrix, by the weaker birefringence, by the positive elongation, by the small optic angle, and by the rarity (or complete absence) of twinning.

Pseudomesolite differs from fibrous stilbite in its small optic angle about the positive bisectrix, in the sign of the elongation, in the magnitude of the maximum extinction angle in sections parallel to the elongation, in the slightly weaker birefringence, and in the rarity or absence of twinning.

Magnetite is not rare as a secondary mineral.

Hematite is especially common at Carlton peak, appearing in nearly all the original minerals as soon as they begin to alter. It occurs in the form of very minute particles and lamellæ, usually along cleavage or fracture lines. In thin section hematite is transparent only when in very thin scales, whose color is blood red; the color by reflected light is always red with metallic luster. A weak pleochroism can sometimes be detected with:

n_g = blood red.
n_p = slightly paler red.

The absorption is therefore: $n_g > n_p$

In thin section it is nearly impossible to distinguish hematite from göthite, which has all the characters above noted. To make this distinction a part of the rock highly altered was heated over the Bunsen burner for half an hour, and a thin section then made. This section showed that the mineral was hematite, since the heat had in no way affected it. The hematite has not been observed to alter except perhaps to magnetite.

Pyrite and *Limonite*. The alteration of the magnetite is not

*Scolecite may contain considerable sodium.

rare; the process is always exogenetic, as already described. The result of the alteration of the magnetite is limonite; and occasional particles having the characteristic color and lustre of pyrite can be detected. Both minerals are opaque; pyrite has a brass yellow color and bright metallic lustre by reflected light, while limonite has a dull or silky lustre and a grayish white color. Pyrite occurs as particles neither fibrous nor lamellar; limonite is rather confusedly fibrous.

One other mineral occurs which it has been impossible to identify. Only three microscopic crystals have been found and therefore no chemical examination is possible. Distinct crystal outline is common, but unfortunately the only crystal of definite orientation has lost nearly all of its outline. An approximate measure gave 119° indicating that the mineral is probably hexagonal. Another crystal of indefinite orientation but with sharp outlines is shown in Plate XVII, Fig. 8, with the angles as measured. No twinning nor any distinct cleavage has been observed. In a very thick section the mineral is yellow with distinct, though weak pleochroism as follows:

n_g = orange yellow
n_p = honey yellow

The interference figure from what is probably a basal section is a black cross with no perceptible change on rotation. The mica plate shows that the mineral is positive. The refringence is slightly less than that of apatite. The birefringence is at least medium strong—the thickness of the section prevents a closer estimate. The extinction is parallel or very nearly so, and the elongation is positive.

The mineral occurs in a highly altered area; but its good crystal outlines make it probable that it is not secondary; it is often immediately surrounded by magnetite and hematite* which are in part at least secondary.

Chemical composition of the plagioclasyte. An analysis of the plagioclasyte from Carlton peak, Minn., gave results under I. in the table; for purpose of comparison a few other analyses are given:

*In one case apatite encloses all three minerals; but this association with apatite is probably accidental. This occurrence however is another indication that the mineral is not secondary.

	I	II	III	IV
SiO_2	40.78	47.40	53.43	46.24
TiO_2				
Al_2O_3	29.37	29.74	28.01	29.85
Fe_2O_3	.34		.75	1.30
FeO	.60	1.94		2.12
MnO	.08			trace
MgO	1.01	.57	.63	2.41
CaO	11.86	13.30	11.24	16.24
Na_2O	4.39	4.99	4.85	1.98
K_2O	.46	1.56	.96	.18
H_2O	1.76	1.64	trace CO_2	1.03
	99.80	101.14	99.87	101.35
Sp. Gr.	2.676	2.704	2.673	2.85

I. Plagioclasyte from Carlton peak, Minn. No appreciable traces of BaO, SrO, nor TiO_2. P_2O_5 not determined.

II. Plagioclasyte from near Encampment island, Minn.; By C. Palache Univ. of Calif. See A. C. Lawson: Bull. No. 8. Geol. & Nat. Hist. Surv. Minn. 1893. p. 6.

III Plagioclasyte from near Nain, Labrador; by A. Wichman: Zeitsch. d.d. Geol. Gesell. 1884.

IV. Plagioclasyte from mouth of Seine river, Ont., by William Lawson; Reported by A. P. Coleman. Jour. Geol. IV. 1896. p. 907-11.

Repeated tests for titanium gave uniformly a negative result. It is not considered probable that this difference from the other gabbros will prove constant. No test was made for phosphoric acid, but, from the extreme rarity and small size of the apatite crystals, no more than a trace would be found. No appreciable amount of barium or strontium exists in the rock; no test was made for lithium. The rock has, as a whole, the composition of labradorite, which is natural, since at least nine-tenths of the rock is pure feldspar.

CHAPTER V. Troctolyte.

Troctolyte is the name proposed by Bonney* in 1885 to designate a rock essentially composed of olivine and plagioclase, with very subordinate diallage. The German term forellenstein is applied to a rock of practically the same composition. The rock styled troctolyte in this article has the typi-

*T. G. Bonney: Geol. Mag. 1885. p. 439. Ref. Kemp. Handbook of Rocks. p. 168.

cal composition as described by Bonney with the unimportant exception that the pyroxene does not always show the diallagic parting. The Minnesota troctolyte is therefore a gabbro consisting of olivine and plagioclase in nearly equal proportions. It varies from the normal gabbro merely in that the ferromagnesian silicate has crystallized almost exclusively as olivine instead of pyroxene. Troctolyte occurs near Duluth, near Gabbro lake, and in varous other localities in the gabbro area as noted by N. H. Winchell and A. H. Elftman. While surrounded by gabbro, the rock has not yet been found grading insensibly into the latter; no contacts have been found. The structure of the rock is generally massive and coarse, but often shows also a certain banded arrangement of the minerals on too large a scale to be seen in hand specimens. A bedded structure is also reported as quite common.* Its relations in the field to the ordinary gabbro have not been fully determined, but it is very probable that it is merely a local variation of the latter like the plagioclasyte. The color is a very dark, mottled, greenish gray; in the background of greenish-black olivine, cleavage faces of plagioclase are abundantly scattered. The rock weathers to a dark green or rusty brown color, which is often mottled with dull, yellowish white decaying feldspars.

Under the microscope the TEXTURE is seen to be coarsely, or medium grained, granitic. The olivine and labradorite are in general mutually xenormorphic, but when augite occurs it shows a marked tendency to surround the olivine, and may even surround many grains of varying orientation thus producing the poikilitic texture in the midst of the prevailing granitic habit. (See plate XVII, Fig. 9.) Occasionally the olivine shows a much rounded crystal form indicating its solidification slightly before the feldspar. Magnetite, as an original mineral is remarkably rare while apatite is wanting altogether, at least in the sections examined.

The alteration products observed in this rock are very few in number. Bowlingite and magnetite are the only secondary minerals at all common; penninite, calcite, and a sericitic mineral, probably muscovite, occur quite rarely.

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*A. H. Elftman: Twenty-third Annual Report, Geol. Nat. Hist. Surv. Minn. 1895. p. 224.

CONSTITUENT MINERALS. *Olivine* is perhaps the most abundant mineral of the rock. The xenomorphic habit prevents any distinct crystal outlines. The cleavages parallel to g^1(010) and p(001) are often well developed. The mineral is dark green in mass, but this is largely due to the decomposition which is fairly advanced.

The beginnings of alteration to bowlingite are everywhere visible; the abundance of the magnetite which separates out at the same time is good evidence that the olivine is very rich in iron.

Labradorite is the feldspar of the rock. It shows the customary twinning according to the albite, pericline and Carlsbad laws. The refringence is always higher than that of Canada balsam; the birefringence is low. The extinction angle in Sn_g is 31°-33°. The extinction on cleavage pieces parallel to p(001) varies from 7° to 11°; on pieces parallel to g^1(010) it is very near 25°. The maximum equal extinction in the zone perpendicular to g^1(010) is at least 38°. It is thus clear that this feldspar has a composition very near Ab_3An_4.

More rarely the angle of extinction in Sn_g is as low as 22° or 23°, while the only two sections perpendicular to n_p which have been found have given extinctions of 67° to 69°. This is considered to be a labradorite near Ab_1An_1.

The *augite* shows the customary prismatic cleavages, with rare parting parallel to h^1(100). Twinning parallel to h^1(100) is not uncommon.

The dispersion is weak; $\rho > \upsilon$ about n_g, the acute bisectrix. The maximum extinction angle in the zone of the vertical axis is slightly more than 40°.

The brown lamellæ characteristic of bronzite are only rarely seen. Liquid inclusions are also rare.

Magnetite is very rare as a primary mineral, and very abundant as a sort of bye product in the alteration of the olivine.

Bowlingite is abundant in the troctolyte. It is nearly always fibrous and the fibers or lamellæ arrange themselves so as to nearly compensate each other's optical properties. Cleavages parallel to h^1(100) occur. The color is variable in the greenish and brownish-yellow tints with weak pleochroism:

n_g =	greenish brown	dark brown
n_m =	brown	brown
n_p =	pale greenish yellow	yellowish brown

The absorption formula is therefore: $n_g > n_m > n_p$.

The refringence is lower than that of olivine; the birefringence is masked by compensation, and apparently does not exceed .015. The mineral usually seems nearly uniaxial, but when no superposition and compensation interferes 2E may attain at least 32°, as measured (*2d*) in the troctolyte. It is often possible to see clearly that the fibers mutually compensate, and it is believed that to such a cause can properly be attributed the low birefringence, the small apparent optic angle and the weak pleochroism often seen. The direction of the fibers is positive or negative with parallel extinction. Bowlingite alters sometimes to chlorite.

Penninite occurs very rarely in minute flakes as an alteration product of the labradorite. It may be sometimes derived from bowlingite.

Calcite is a rare alteration product of labradorite.

THE CHEMICAL COMPOSITION of the troctolyte shows a high per cent of titanium. The protoxide of iron and the magnesia are naturally high.

	I
SiO_2	35.81
TiO_2	2.30
Al_2O_3	14.32
F_2O_3	7.38
FeO	15.25
MnO	.18
MgO	10.49
CaO	17.23
Na_2O	2.06
K_2O	.37
H_2O	5.25
	100.62
Sp. Gr.	3.07 -3.10

I. Troctolyte from near Duluth, Minn. No appreciable BaO, nor SrO.

PERIDOTYTE.

Peridotyte occurs only rarely in Minnesota and the writer has not been able to obtain even a single specimen. It doubtless represents the ultrabasic portions of the gabbro magma and is rare in proportion as the plagioclasyte, the relatively acid part of the magma is common. Its composition is said to be essentially: pyroxene, usually augite, olivine, and a varying, but very small, amount of labradorite. It is thus a picryte.

CHAPTER VI. Orthoclase Gabbro.

This rock was first described by Streng* in 1877 as a hornblende gabbro, since he considered the amphibole to be an original mineral. With this exception, his description is quite accurate, though rather summary.

Irving,† in 1880, pointed out the importance and prevalence of the orthoclastic constituent of the rock, and gave it the name orthoclase gabbro; later, he‡ showed that the amphibole was often, if not always, secondary.

Orthoclase gabbro differs from normal gabbro essentially in containing a notable amount of monoclinic feldspar.

It occurs in great abundance near Duluth, and at several other points in Minnesota and Wisconsin. It forms at Duluth the southern limit of the gabbro area, rising in high hills and bold bluffs back of the city. In structure it is massive, and irregularly jointed; diaclases run in every direction, and the faces of the resultant high ledges form all angles with one another. Besides the jointing, the rock often seems to be rudely stratiform. It is usually very coarse in grain, and all the essential constituents are easily seen with the naked eye. The color is variable, depending upon the prevalence of orthoclase and hornblende. The prevalent type is of a light gray color, but this is changed to dark green when amphibole is abund-

*A. Streng und J. H. Kloos: Ueber die krystallinischen Gesteine von Minnesota in Nord Amerika. Neues Jahrb. f. Miner. etc. 1877. p. 31. Translation in 11th Ann. Rep. Geol. Nat. Hist. Surv. Minn. 1883.

†R. D. Irving: Geology of Wisconsin. Vol. III. 1880.

‡R. D. Irving: On the paramorphic origin of the hornblende of the crystalline rocks of the northwestern States: Amer. Jour. Sci. 1883, XXVI, p. 27; Ibid. 1884, XXVII, p. 130.

ant, and to reddish gray when orthoclase predominates. The plagioclase crystals are conspicuous on fresh surfaces, and single cleavage faces may be even three to four centimeters in length. The augite and secondary hornblende are usually much less abundant, but occasionally they also form large crystals. Orthoclase is conspicuous from its red color, which is due to fine hematite dust scattered through it everywhere. Magnetite often forms masses whose black metallic luster is clearly determinable. Acicular, colorless apatite needles are usually abundant, and visible even without a magnifying glass. Less commonly the rock is of finer grain and then the color is darker and the pyroxene more abundant. On decomposition the rock usually becomes darker, and the ferromagnesian minerals become more conspicuous, and can be seen to fill the areas between the decaying feldspars.

Under the microscope the dominant TEXTURE is seen to be very coarsely granitic, but the plagioclase sometimes shows a tendency to enclose the augite in poikilitic fashion. The feldspar is in very large crystals, which may even occupy the whole of the section. The augite, next older, sometimes shows good crystal outlines wholly surrounded by feldspar, which in some cases has protected the pyroxene from uralitization. The earliest minerals formed were the magnetite, usually in small masses and not abundant, and the apatite, in large crystals. But the mineral especially characteristic of the rock is the orthoclase, which, is clearly younger than the plagioclase.

CONSTITUENT MINERALS. *Labradorite* is the dominant feldspar of the orthoclase gabbro; it is usually in very large anhedra, in which twinning is usually rare. The mineral is positive with $\rho > v$ about n_g, the acute bisectrix.[1] The extinction in S n_g is about 20°, and in T n_p it is as high as 62° to 64°; perpendicular to an optic axis the extinction is 41°, while the maximum extinction in the zone of symmetry of the albite twinning exceeds 30°. The extinction in cleavage pieces parallel to p(001) is—4½° to 6°, and parallel to g^1(010), it is about —18°. The composition is therefore near Ab_1An_1.

The labradorite, in large anhedra, is often surrounded by a more recent crystallization of orthoclase, which sometimes

even penetrates far into the plagioclase (see plate XI, Fig. 2). The line of contact between the labradorite and orthoclase is often difficult to find.

The labradorite contains large crystals, often well formed, of augite, and others of apatite. Magnetite is practically absent, both in the acicular form and also as the fine dust which is so common elsewhere. But the labradorite has not escaped from the alteration processes which have so changed the rock; it contains many decomposition products, especially flakes of hornblende and clinochlore; sometimes the hematite particles have penetrated along fractures and around diallage inclusions. Further the cleavages have sometimes opened, giving the appearance of fine twinning.

Andesine is rather common, but clearly subordinate in abundance. The optic angle is very large, and the mineral sometimes negative. The dispersion about n_g is $\rho < v$, differing from labradorite. The extinction in sections perpendicular to n_g is about 10°, perpendicular to n_p it is 66°-68°. Andesine shows the same inclusions and alterations as the labradorite.

Orthoclase occurs surrounding and even penetrating the plagioclases (see plate XI, Fig. 2). Carlsbad twinning is remarkably rare. This feldspar, seen in mass, has a dark pink tint due to the innumerable inclusions of hematite. The mineral is optically negative, and from the measure of $2d$, the value of 2E is 71° 4′ or, if N=1.523, 2V=44° 52′. It has been possible to determine that the extinction in sections perpendicular to n_p is 90°, while in those perpendicular to n_g it does not seem greater than +4°. This orthoclase does not belong to the deformed variety, since the plane of the optic axes is parallel to $g^1(010)$.

The inclusions are extremely numerous, and nearly all of them seem to be of recent origin. Besides the hematite particles, flakes and crystals of hornblende are very common, while chlorite, epidote and titanite are more uncommon. The last two occur in highly altered areas, sometimes showing evidence of pressure and now changed to what may be called saussurite. Sometimes the orthoclase is optically broken up into many parts, while physically still intact; at other times it has been actually broken up into a fine granular aggregate

of orthoclase, with calcite, epidote, and more rarely, quartz, and titanite. Careful search for albite has been in vain.

Pyroxene is comparitively rare, having usually altered to hornblende.It sometimes shows remarkably good crystal outlines with the common faces: $p(001)$, $h^1(100)$, $g^1(010)$, $m(110)$, and $b^{1/2}(\bar{1}11)$. The pyroxene is very pale green to colorless and only pleochroic in thick sections, with:

n_g = cloudy olive green.
n_m = faintly yellowish green.
n_p = greenish brown.

The refringence is very high ; the birefringence is only medium with:

$$n_g - n_m = .017 \text{ at least.}$$
$$n_m - n_p = .004 \text{ at least.}$$
$$n_g - n_p = .021 \text{ at least.}$$

The angle ot the optic axes, as indicated by the birefringence, seems to be unaccountably small; the measures of $2d$ gives $2E = 56° 36'$. The maximum extinction angle in the vertical zone is at least 45°.

The pyroxene does not seem to change to hornblende part by part in this rock; but each crystal seems to change gradually, every part of the crystal changing at once. Thus, the mineral may be seen becoming slightly green, then deeper green, and finally dark green hornblende appears, which is strongly pleochroic, and has changed cleavages and increased birefringence.

The optic properties of this pyroxene suggest that it could probably be referred to the abnormal variety, "pigeonite," described above. (See chapter III).

Magnetite is very rare as an original constituent, and usually occurs in very small grains. On the contrary it is very abundant as a secondary mineral. It has been proved repeatedly that this magnetite is titaniferous,* a fact which doubtless explains the high per cent of titanium in the rock, since the pyroxene shows no signs of containing any appreciable amount. The octahedral parting and strong magnetic character prevent any confusion with ilmenite.

Apatite occurs in two different forms between which there

*See Irving, op. cit. p. 266.

seem to exist no graduations: First, large crystals from about one-half a millimeter to more than one millimeter in diameter, and sometimes exceeding one centimeter in length; and secondly, extremely minute crystals whose presence would often be unobserved, but for the halos which they cause in the hornblende. The large crystals are usually rounded and sometimes deeply corroded (See plate XVIII, Fig. 10 and 11); while the minute crystals have never been seen except in well preservd crystals. The large crystals occur in every part of the rock, the small crystals are exclusively confined to certain areas; and seem to represent the material derived from the corrosion of the large crystals.

The large colorless crystals are often slightly clouded by great numbers of inclusions, which are rare or absent in the small crystals. The large crystals have shown in sections well oriented the faces: *p*(0001), *m*(10$\bar{1}$0), (11$\bar{2}$0), (21$\bar{3}$0), (10$\bar{1}$1), and probably the rare face (43$\bar{7}$1). The last face was found in a section strictly parallel to the vertical axis. The angle between the prism face (1$\bar{1}$20) and the pyramidal face (43$\bar{7}$1) varied between 11° 15′ and 12° 15′, since the latter was not absolutely straight and regular. E. S. Dana* found a pyramidal face on a crystal from Paris, Me., which was likewise somewhat irregular, and his goniometric measures varied between 11° and 12°, from which he calculated that the face was (43$\bar{7}$1), making, theoretically, an angle of 11° 56′ with the face (11$\bar{2}$0).

Cleavage parallel to the base *p*(0001) is distinct, but imperfect; parallel to one or more prism faces it occurs very imperfectly.

The most peculiar feature of the apatite† is its marked biaxial character about *//D*. Careful measurements of *2d* show that 2E often exceeds 10°!

At the same time crystals occur which seem strictly uniaxial.

Crystals optically biaxial were carefully separated and freed from all impurities with the aid of the microscope. Microchemical tests demonstrate the existence of potassium in this apatite; the test with platinic chloride gave crystals shown in plate XVIII, Fig. 13, and that with bisulphate of bismuth gave the forms shown in plate XVIII, Fig. 14. Further am-

*E. S. Dana: Amer. Jour. Sci. 1884. XXVI. p. 480.

monium molybdate and sulphuric acid gave excellent tests for phosphoric acid and calcium respectively.

The inclusions in this apatite are very various. They are:

1. Solid. Besides the masses of orthoclase, hornblende, magnetite, and actinolite (see plate XVIII, Fig 12) introduced by corrosion there are:

a. Dustlike particles, wholly irregular in shape and arrangement, usually rather sparingly, but evenly distributed. These are opaque and black; probably magnetite.

b. Irregularly spherical particles frequently arranged along planes either transverse or curving and composed of magnetite.

c. Acicular black inclusions having their long axis always parallel to the elongation of the apaatite. They are very minute, opaque and black, and probably composed of magnetite.

2. Cavities containing:

a. A single liquid of high refringence.

b. A single liquid of low refringence.

c. A gas.

d. A solid black particle (magnetite).

e. Two liquids, one enclosed by the other, and possessing different indices of refraction.

f. A liquid and a gas: the latter in the form of a bubble sometimes possessing rapid rotatory motion, and sometimes capable of displacement from side to side of the cavity.

g. A liquid and a solid particle, apparently of magnetite.

These cavities are usually nearly spherical; occasionally they show fantastic shapes, always curved. Thus, a sort of triple form is shown in figure 15A; an inclusion with a double border in figure 15B; and the curious case of two cavities connected by a sort of curved canal in figure 15C.

The cavities are sometimes arranged along curving planes which are not however, the same planes as those containing magnetite particles ,but they are oftener scattered irregularly through the whole crystal. Such inclusions, except the dust particles, do not occur commonly in the other minerals of the rock.

Finally, during the alteration of the rock, hematite and even biotite (see plate XVIII, Fig. 12), have penetrated into any fractures existing in the apatite.

Hornblende is by far the commonest and most important mineral formed since the final consolidation of the rock. It shows only the outlines of the pyroxene with its own prismatic cleavages. It is compact, or, more rarely, fibrous. When the pyroxene was twinned, the hornblende is twinned similarly. The color is dark green, both in mass and in thin sections, with strong, but variable, pleochroism:

n_g = green	dark bluish green
n_m = yellowish green	green
n_p = yellow	greenish yellow

The absorption is $n_g > n_m > n_p$.

The birefringence is notable with:

$n_g - n_m = .008$ at most.
$n_m - n_p = .015$ at most.
$n_g - n_p = .023$ at most.

Hornblende is optically negative, and the value of the acute optic angle derived from the measure of $2d$ is: $2E = 74°$ about.

The maximum extinction angle in the vertical zone is at least 18°.

Hornblende contains inclusions of minute apatite crystals surrounded by marked green halos. It alters rarely to chlorite.

Actinolite is quite rare in very fine fibers or lamellæ. Like hornblende it is a decomposition product, but it is formed at some distance from the augite masses. It has a pale green color with weak pleochroism.

n_g = pale green
n_m = yellowish green
n_p = (greenish) yellow

The absorption is $n_g > n_m > n_p$.

It has a lower refringence than the hornblende as shown by the fact that:

Actinolite $n_g < n_g$ apatite (while apatite $n_g < n_m$ hornblende).

The birefringence is very nearly the same as that of hornblende and $n_g - n_p = .022$ at least.

The elongation of the fibers is positive and the maximum extinction angle in the vertical zone is 10° at least.

Clinochlore is the chlorite of the rock, and it is the final re-

sult of the transformation of the augite. It is very rare in the sections studied.

Hematite is extremely abundant, but is nearly confined to the orthoclase. It occurs in very minute particles and flakes, and is red by transmitted light as well as reflected light.

Epidote occurs in small anhedra. It has a pale green color and determinable pleochroism as follows:

n_g = yellowish green
n_m = yellow (greenish)
n_p = pale yellow

The absorption is: $n_g > n_m > n_p$.

The refringence is very high, and the birefringence strong with:

$n_g - n_m = .012$ at least.
$n_m - n_p = .025$ at least.
$n_g - n_p = .037$ at least.

Titanite is very rare. It occurs in irregular grains without any good cleavage. The birefringence is very strong; but $n_m - n_p = .008$ at most. From the measure of $2d$, the angle of the optic axes $(2E) = 40°$ about.

Quartz and *calcite* are rare alteration products, only found in highly altered areas.

The CHEMICAL COMPOSITION of the orthoclase gabbro shows that the rock is unusually rich in titanic acid; which is probably to be attributed chiefly to the magnetite; the magnesia is low, and the manganese quite notable. The phosphoric acid is abundant; the potassium undoubtedly belongs to the orthoclase, while the relative amounts of calcium and sodium show that the dominant feldspar is labradorite. Streng's analysis (II) is added for comparison.

It is evident from the mineralogical and chemical composition that this rock is, in a certain measure, to be compared with a monzonyte. It possesses certain characters of the monzonytes, such as low per cent of magnesia, richness in calcium, of which there is an excess, and relatively high content of alkalies; however the latter are in less quantity than in the monzonytes, and the sodium oxide exceeds the potash, in spite of the presence of orthoclase, whereas the reverse is characteristic of monzonyte.

	I	II	III
SiO_2	52.48	49.15	45.65
TiO_2	1.26	.18	1.66
Al_2O_3	15.47	21.90	15.20
Fe_2O_3	5.14	6.60	6.71
FeO	9.25	4.54	13.81
MnO	.51		.71
MgO	2.55	3.03	2.95
CaO	7.27	8.22	6.33
Na_2O	3.26	3.83	3.09
K_2O	1.75	1.61	1.05
H_2O	1.24	1.92	2.29
P_2O_5	.29	.33	.25
	100.47	100.80	99.70
Sp. Gr.	2.81		2.84
	-2.84		-2.86

I. Orthoclase gabbro fairly rich in orthoclase, (1797) from Duluth, Minnesota, No appreciable BaO nor SrO; F not determined.

II. "Hornblende gabbro," from Duluth, Minn.; by A. Streng: Neues Jahrb. f. Miner. etc. 1877. p. 177. MnO and Fl not determined. TiO_2 and P_2O_5 determined separately, and not included in the total.

III. Orthoclase gabbro (1797), rich in hornblende, from Duluth, Minn. No appreciable BaO nor SrO; F not determined.

The orthoclase gabbro constitutes therefore an intermediate phase between the family of gabbros and that of the monzonytes, and is not a monzonyte properly speaking; the name proposed by Irving, and here used, is therfore to be retained.

ORIGIN. In conclusion, the reasons for which the orthoclase occurs as a real agent of corrosion in relation to the plagioclases and other elements of this rock call for discussion.

Several possible explanations present themselves:

1. Introduction of the orthoclase by means of infiltrating waters after the consolidation of the rock.

This theory would explain very well the abundance of hematite and other alteration products in the rock, but it cannot explain the constancy of orthoclase everywhere in such a large mass. It is therefore to be rejected.

2. Production of the orthoclase by exomorphic metamorphism exercised by numerous dikes of orthoclastic rocks (augitic syenytes, etc.) which cut the rock here under discussion.

This theory would explain very well the corrosion which the older elements of the rock have suffered, notably the feldspar and the apatite; it would explain the modifications which the pyroxene has suffered; but the same difficulty presents itself as in the preceding case; and, moreover, if such exomorphic phenomena are common in fragmentary rocks enclosed within volcanic rocks, it is still difficult to understand how they could exist in such constancy throughout so large a mass.

3. The last hypothesis, and the one explaining best all the phenomena, consists in supposing that the orthoclase is an original element of the magma and crystallized directly from the latter.

The corrosion of the other minerals of the rock which it has caused is then of the order of that which is often seen in the phenocrysts of the volcanic rocks when they have a composition differing from that of the analogous minerals, of the second consolidation, and of the order of that so often seen in the zonal plagioclases of the endomorphosed deep-seated rocks, etc.

As for the cause of the differences of composition between this orthoclase gabbro and the other gabbro types described in this paper; a careful study of the local field geology will perhaps enable one to see if it does not bear a relation to the position of this rock at one of the extremities of the gabbro region, and to determine if it is not connected with the nature of the older rocks in contact with which the orthoclase gabbro finally solidified.

Chapter VII. Cordierite Noryte.

The term noryte was proposed by Esmark* in 1838 to designate certain rocks of widespread occurrence in Norway, consisting essentially of plagioclase and hornblende, with or without accessory diallage, or hypersthene. In current usage, however, noryte signifies a holocrystalline granitoid rock consisting essentially of a plagioclase feldspar and a rhombic pyroxene; and it is in this sense that the word is used in this article. A typical noryte, therefore, differs from a normal

*Esmark: Magas. f. Naturvid. 1838, I. p. 207 Ref. Zirkel: Petrog. 1894. II. pp. 785.

gabbro only in the replacement of the monoclinic by a rhombic pyroxene.

The noryte studied came from Sec. 15, T. 63 – 9, a short distance northwest from Snowbank Lake. It is at the northern edge of the gabbro area, where the latter comes in contact with Archean clastic "greenstones." Furthermore, this type of rock is not uncommon along the northern line of contact of the gabbro mass with the older schists, and it is never found away from the contact zone. This rock has been termed "muscovadyte"* or latterly, biotite noryte, by the Minnesota Survey.

It is usually very dense, and fine grained, and shows very little evidence of schistosity. On the other hand, it occurs in beds often of great size, which sometimes have a recognizable dip and strike, and are associated with "greenstones" (Keewatin) probably of sedimentary origin. The strike and dip of these masses of noryte always follow the direction of the contact plane between the gabbro and the earlier Keewatin sediments. That is, they are nearly horizontal and extend from N. E. to S. W. These masses occur quite commonly at many different points along the northern edge of the gabbro area, e. g., at Gunflint lake, Birch lake, Gabimichigama lake, Disappointment lake, near Little Saganaga lake, etc. The transition from the ordinary gabbro to the "muscovadyte" has been repeatedly described, as well as the transition from mica schist to "muscavadyte," as they occur in the field, and in both cases the changes are very gradual, by imperceptible degrees. The type which we are studying forms a part of the altered gabbro rather than the metamorphosed schist. It is, further, of interest to note that similar poikilitic and granular rocks (containing cordierite?) have been found as contact phases of the gabbro in the Adirondacks of New York state by H. P. Cushing.

The color of the rock on fresh surfaces is a dark gray, sometimes slightly greenish; on such surfaces the bright scales of biotite are very conspicuous, in a finely granular glassy background. Occasionally a yellowish green mineral can be

*The name muscovadyte is derived from the Spanish "muscovado" (brown sugar) and refers to the brown color of surfaces exposed to weathering.

seen. When fresh the rock is remarkably tough and tenacious. On exposure to the weather it becomes yellowish brown to dark greenish brown, through the oxidation of the iron. At the same time it loses in density to a remarkable degree, and often becomes so soft that it can be crumbled easily with a hammer.

Under the microscope the TEXTURE is seen to be finely granular and poikilitic. (See plate V, figure 1.) The latter texture is especially noticeable in the relation between the biotite and cordierite, but with the nicols it is discovered that both the former, and the bronzite are enclosed by large quartz grains which are poikilitic in their relation to the other minerals, but xenomorphic in their relations to one another. Feldspar is so rare that it has little effect upon the texture of the rock as a whole; the four common minerals are cordierite, bronzite, biotite, and quartz. Of these the cordierite is the oldest, and countless grains of it are included within each of the other three; bronzite is next in age and while containing grains of cordierite it is often itself surrounded by biotite or quartz. Biotite always formed before the quartz, and is often enclosed by it.

The accessory minerals of the rock include enstatite, magnetite, pyrite, apatite, zircon, staurolite,* and, more rarely, epidote and spinel. The only products of posterior decomposition observed are anthophyllite, muscovite, and an undetermined mineral.

STUDY OF THE MINERALS. The dominant *plagioclase* of the noryte is slightly more acid than the labradorite of the normal gabbro. It is in much smaller grains, and much less abundant in the noryte; crystal outline is wanting entirely. The albite and pericline types of twining occur. The acute bisectrix is n_g; the optic angle is large. The extinction in Sn_g is 19°—22°; Tn_p it is 63°—64°; the maximum equal extinction on both sides of the albite twining line exceeds 30°; the extinction perpendicular to one of the optic axes is somewhat variable, being about 38°—41°; the extinction in cleavage pieces parallel to $p(001)$ is 5° to 6°, and parallel to $g^1(010)$ it is 20° to 22°. The composition of the labradorite is therefore near $Ab_1\ An_1$.

*Contains graphite inclusions.

More rarely the feldspar is slightly more acid, and is referable to *andesine* of the composition $Ab_1 An_1$ about. The extinction perpendicular to n_g is then about 10°, and perpendicular to n_p from 66° to 69°. In cleavage pieces parallel to $p(001)$ the extinction is sensibly parallel; parallel to $g^1(010)$ it is about—9°.

The plagioclase very rarely shows the zonal structure; undulatory extinction is uncommon.

Inclusions in the feldspar are rare; liquid inclusions occur, as well as a few solid particles.

Both *bronzite* and *enstatite* exist in the rock, though the former greatly predominates in sections studied. Both occur in rounded grains sometimes showing a tendency to crystal form, but with the angles always rounded. The prismatic cleavages are large and interrupted. In thin sections of not more than .03 mm. thickness enstatite is wholly colorless; bronzite is sometimes colorless and sometimes tinted very pale yellowish green with very feeble pleochroism as follows:

n_g = pale green.
n_m = pale yellowish green.
n_p = pale yellowish to colorless.

The absorption is $n_g > n_m > n_p$.

The refringence is very high, but the birefringence is weak, with:

	Bronzite.	Enstatite.
$n_g - n_m$ =	.004 at least.	.005 at least.
$n_m - n_p$ =	.007 at least.	.003 at least.
$n_g - n_p$ =	.012 at least.	.008 at least.

The ordinary pyroxene (bronzite) of the rock is negative, and would therefore be called hypersthene, if the very pale color did not show that it is decidedly low in iron. Enstatite, on the contrary, is positive. Both have large optic angles.

The pyroxenes contain many liquid inclusions, sometimes quite large. They contain more rarely masses, and needles of magnetite. Finally they sometimes enclose anhedra of cordierite and minute flakes of biotite. They alter to anthophyllite, as will be described later.

Biotite is abundant; it never shows crystal outline, but encloses other minerals, never bending around them. It pos-

sesses perfect cleavage parallel to the base, and in sections parallel to the base the pleochroism is scarcely perceptible; in other sections it is strong with:

n_g = clear brown.
n_m = reddish brown.
n_p = pale yellow.

The absorption is $n_m > n_g > n_p$, but n_m and n_g are nearly equal.

The refringence is high and the birefringence very strong:

$$n_g - n_p = .050 \text{ at least.}$$

The mineral is negative and often very nearly uniaxial, but sometinmes 2E is as large as 5° 42′ (measured by *2d*).

No percussion figure has been obtained, but the cleavage fragments parallel to the base frequently show a separation plane which must be parallel to g^1(010), and occasionally nearly complete hexagons occur, through the presence of parting probably parallel to $b^{1/2}$(111). Repeated examination shows that the optic plane is always perpendicular to the easiest plane of separation g^1(010), and the mica is therefore the rare variety anomite.

The *anomite* encloses rounded and subangular grains of cordierite, sometimes showing its characteristic twinning, and bronzite. It contains more rarely crystals and needles of magnetite, masses of pyrite, crystals of apatite and zircon. Around the last two, greenish pleochroic halos are usually developed, especially intense around zircon. A remarkable halo is represented in Fig. 16. It is developed in biotite along its contact with enstatite. Many other similar contacts show no sign of halo, but one other analogous occurrence has been noted.

Cordierite is not at all uncommon in the noryte, but since it is wholly colorless and devoid of the pleochroic halos commonly found in it, its determination is a matter of considerable difficulty. As it has never before been reported in granular igneous rocks of the labradoritic series, it deserves special attention. Crystal outline is quite common, but the angles are always rounded, and formless grains are abundant. The faces observed are: p(001), h^1(100), g^1(010), $b^{1/2}$(111), and as twining faces: $m(1\bar{1}0)$ and g^3(130).

Cleavages are very rare, if not entirely absent. This cor-

dierite in color, lustre and transparency is entirely comparable to clear quartz. The refringence is low, but in this rock:

Cordierite $n_m > n_p$ quartz.
Cordierite $n_g < n_m$ labradorite.

The birefringence is slightly higher than that of quartz and gives pale yellow as the maximum interference color. The mineral is negative, and about n_p the optic angle is too large to permit measurement with an ordinary microscope. The elongation is negative with extinction parallel.

Practically the only way to make a certain determination is to search with high powers, (since the grains and crystals are very small in this rock), to find the twinning characteristic of the mineral.

There are two methods of twinning: in both the vertical axis is the twinning axis, about which the rotation is 60°. In the first the face of association is $m(1\bar{1}0)$ and in the second it is $g^2(130)$. Both types produce pseudohexagonal forms when repeated. They may also give rise by interpenetration to polysynthetic bands very similar to those of the feldspars. Such bands may be seen in sections parallel to $p(001)$, and also in sections parallel to $g^1(010)$ and $h^1(100)$. In the first case they show symmetrical extinction of 30°; in the second case they extinguish together parallel with the twinning line, but show different birefringence.

A section parallel to $p(001)$ showing either type of twinning is sufficient to distinguish cordierite from all other minerals, including the feldspars. For, in the cordierite, every individual of the twin will be strictly perpendicular to n_p, and the extinction will be symmetrical, at 30° from the twinning line, while among feldspars the only ones which can show n_p sensibly perpendicular in every individual are oligoclase and oligoclase-andesine, in which the symmetrical extinction on each side of the twinning line cannot exceed 7° or 8°.

The optical orientation in the first type of twinning is shown in Plate XVIII, Fig. 17, while Fig. 18 shows the second type, as well as twinning by interpenetration; both figures were drawn with a camera lucida from thin sections of the cordierite noryte (983).

When crystal outline is present, sections perpendicular to n_g, the obtuse bisectrix, can be distinguished from other color-

less minerals, except certain oligoclases (which do not occur in the noryte), by the very large optic angle and the parallel extinction. Such sections are rectangular with rounded angles and negative elongation.

The cordierite contains spherical and acicular liquid inclusions, and particles of magnetite which are nearly always coated with a very thin layer of green spinel. But the most characteristic inclusions, which, when present, even serve to identify the cordierite, are minute short prisms of staurolite. They also serve to show the orientation of formless grains of cordierite, since the vertical axes of the two minerals are nearly always parallel.* In spite of these numerous inclusions the cordierite shows no trace of the pleochroic halos usually so common in this mineral.

Quartz occurs in large granular masses enclosing the cordierite, biotite and bronzite. It shows no crystal outlines nor cleavages. It contains minute liquid and solid inclusions.

Magnetite is usually in the form of very small rounded grains, widely, but sparsely, distributed. It occurs also as a fine dust. Crystal outline is very rare, and the grains are only occasionally large enough to give the characteristic blue-black metallic reflections. The mineral is often coated with a thin layer of green spinel.

Pyrite is nearly always xenomorphic; it is occasionally as abundant as the magnetite.

Staurolite occurs in extremely small microscopic prisms, often nearly as dark colored as biotite. The crystal form is nearly always well developed, and the outlines are usually rectangular. The faces observed are: $p(001)$, $g^1(010)$, $h^1(100)$, and more rarely $a^1(101)$, and $[m(1\bar{1}0)$ (?)$]$. No twinning nor cleavage occurs. The color is a golden yellow with distinct pleochroism:

n_g = dark golden yellow.
n_m = yellow.
n_p = pale yellow or colorless.

The absorption is therefore $n_g > n_m > n_p$.

The refringence is very high, and the birefringence weak, only giving white and pale yellow. The elongation is positive with parallel extinction.

*See further under staurolite.

Inclusions occur rarely, but they are so small as to escape accurate identification. They are gray, black, and earthy; of wholy irregular outlines, and are believed to be *graphite*.

Staurolite has not been found except as inclusions in the cordierite in which it nearly always has a definite orientation. The elongation of the two minerals is parallel, but of contrary sign i. e., n_g of staurolite is parallel to n_p of cordierite. While the optic planes of both minerals are parallel to the elongation. they are mutually perpendicular, and n_p of staurolite is parallel to n_m of cordierite. Thus sections in the vertical zone showing the maximum birefringence ($n_g - n_p$) of the staurolite. show only a medium birefringence in the cordierite, and vice versa. This relation is shown in Plate XIX, Fig. 19.

Nevertheless the staurolite prisms occasionally occur with an orientation wholly arbitrary.

Zircon occurs in well defined rectangular crystals. Zircon causes intense greenish halos in the anomite, and much feebler ones in anthophyllite. It has not been found in cordierite.

Apatite occurs in very small acicular crystals terminated by the basal plane, or a steep pyramid. The mineral is clearly biaxial, though no measure of the optic angle (extremely small) has been possible.

The apatite sometimes contains liquid inclusions. It causes greenish halos in biotite, not as intense as those due to zircon.

Epidote is very rare; it occurs in irregular crystals, with marked cleavages, and formless grains. The birefringence is variable even in a single crystal but the maximum is ($n_g - n_p$) = .036 at least.

Spinel has only been observed as a very thin coating on magnetite, especially when the latter is enclosed in cordierite. It is very dark green, often opaque, and wholly isotropic. It is probably pleonaste.

Anthophyllite occurs as a fibrous or lamellar alteration product of the bronzite. All stages of this change can be seen from the compact granular bronzite to fibrous amphibole. The alteration usually begins on the borders and follows the rough cleavage lines, developing chiefly in one direction parallel to the fibers. The two minerals usually have parallel orientation and simultaneous extinction. The anthophyllite

is easily distinguished from the pyroxene by its stronger birefringence which gives color as high as blue:

$$n_g - n_m = .013 \text{ at least.}$$
$$n_g - n_p = .023 \text{ at least.}$$

The refringence is always lower than that of bronzite, but higher than that of biotite. Anthophyllite is biaxial and positive with a large optic angle. The direction of the fibers is positive. The color is scarcely noticeable in thin section, with very feeble pleochroism as follows:

n_g = pale green.
n_m = pale yellowish green.
n_p = pale yellowish green.
Absorption $n_g > n_m = n_p$.

Anthophyllite shows rather feeble pleochroic halos about inclusions of zircon. These intensify the ordinary color of anthophyllite.

Muscovite is very rare. It occurs in microscopic lamellæ as an alteration product.

One more decomposition product occurs along fractures in the rock. The color is clear yellow to orange reddish, without perceptible pleochroism. The refringence is distinctly higher than that of plagioclase and lower than that of biotite. The birefringence is at least .010 and may be considerably more as the mineral is rarely as thick as the section. It is positive and uniaxial, or more probably biaxial, with a very small optic angle. The elongation of the fibers is positive with extinction nearly parallel. It is not sensibly attacked by either HCl or H_2SO_4, and consequently some attempted micro-chemical tests failed, leaving the mineral undetermined.

The CHEMICAL COMPOSITION of the cordierite noryte shows much iron and alumina, and little calcium. For comparison two analyses are added of the cordierite norytes described by Prof. Lacroix. It will be noted that the Minnesota rock is distinctly more basic than those of Pallet. A further discussion of this analysis will be found in chapter X.

The fourth analysis represents a Minnesota rock, which can be considered to represent a stage intermediate between the normal gabbro, and the noryte studied in this article. It is less acid and less highly aluminous; on the other hand, it

is richer in iron, and contains a remarkably large amount of magnesia. A feature of the analysis, pointing to peculiar conditions of origin, is the complete reversal of the ordinary ratio between the sodium and potassium. The very high excess of alumina, while of course partly explained by the presence of biotite, suggests that cordierite was perhaps overlooked in the optic examination of the rock.

	I.	II.	III.	IV.
SiO_2	52.84	58.30	51.30	46.96
TiO_2	trace			.62
Al_2O_3	23.62	22.55	25.20	14.13
Fe_2O_3	.65	2.24	2.91	.76
FeO	10.00	7.13	2.39	14.95
MnO	.43			.93
MgO	3.16	3.90	4.01	15.97
CaO	3.92	1.91	2.50	2.32
Na_2O	2.64	3.21	3.82	.35
K_2O	.67	.59	.79	1.68
H_2O	1.87	.51	.55	1·33
	99.80	100.34	99.47	100.09
Sp. Gr.	2.81 to 2.85	2.84 to 2.86	2.88	

I. Cordierite noryte from Sec. 15. T. 63-9, not far from Snowbank lake, Minn. No BaO nor SrO; ZrO_2 and P_2O_5 not determined.

II. Average of two analyses of a cordierite noryte from the railroad cut between Gorges and Pallet (Loire Infèrieure, France), by Lacroix and Pizani. A. Lacroix: Le Gabbro du Pallet: Bull. Carte Geol. France. No. 67, 1899, p. 23.

III. Cordierite noryte from the quarry of Prinaux, by A. Lacroix: Ibid. p. 23.

IV. Granulitic hypersthene gabbro. From S. E. ¼ Sec. 20, 65-4. Described by Bayley. Jour. Geol. III. p. 1. Contains hypersthene, biotite, diallage, magnetite, and plagioclase. Poor in feldspar. Analysis by H. N. Stokes; Bull, 148. U. S. Geol. Survey. p. 111. Contains also .06 NiO_2, .03 P_2O_5 and trace of Cr_2O_3.

It has been noted that the change from gabbro to "muscovadyte" is by absolutely imperceptible degrees; but the two extremes are radically different. In place of the coarse granular texture of the gabbro appears a very fine granular-poikilitic texture. The coarsely cleavable gabbro is transformed into a rock so dense and fine as to be broken with great difficulty. In structure the massiveness of the gabbro is replaced by more or less evident schistosity, this character becoming more pronounced as the distance from the normal gabbro increases. As one passes from the gabbro to the noryte the rock becomes

darker, often greenish in its fresh condition, while the weathered surface has a conspicuous yellow-brown, rusty color.

These exterior distinctions are accompanied by still more important differences in chemical and mineralogical composition. The most important and abundant mineral in the gabbro is the plagioclase; in the noryte it sometimes becomes so uncommon as to be scarcely more than an accessory constituent. At the same time it frequently becomes more acid in character. The olivine, often abundant in the gabbro, is entirely lacking in the noryte, while the augite of the gabbro is replaced by the pure ferro-magnesian orthorhombic pyroxenes. This mineralogical transformation indicates greater relative richness in iron and magnesia, and comparatively little calcium oxide in the magma; conclusions fully borne out by the chemical analysis.

But various new minerals also appear. Biotite, so far as known, only occurs in the gabbro as a result of alteration usually of the mesogenetic type. In the noryte on the other hand it is one of the common primary minerals, indicating the presence of some potassium not in the feldspar. And, in fact, the potash is perceptibly higher in the noryte than in the gabbro, while the excess of alumina is very marked. There can be no doubt that the biotite is of primary origin since it is not infrequently surrounded by quartz, clearly also derived directly from the magma. The latter mineral furnishes another distinguishing feature since it is almost unknown as a primary mineral (and rare as a secondary product) in the gabbro. But the most interesting among the new minerals is the cordierite, which forms a notable per cent of the rock. Its presence is not only significant and interesting, but it is entirely exceptional both from a mineralogical and petrographical point of view. In fact, until within a few months, this mineral, so abundant in certain granites and metamorphic rocks, was unknown in basic granitoid rocks, and only two or three* oc-

*These occurrences are: in the "Kersantite" from Michaelstein in the Hartz, described by Max Koch (Jahrb. k. preuss. geol. Landesanst. Berlin. 1887. p. 44.); in the "cordierite-vitrophyrite" from near Harrismith (Orange Free State), described by M. Molengraaf (N. Jahrb. f. Miner. etc. I. 1894. p. 79); and MM. Lacroix (Les Enclaves des Roches volcaniques). Prohaska (Sitzb. k. k. Akad Wissensch. Wien, 1883. XVIII.), and Zirkel (Neues Jahrb. f. Min. etc., 1891, I. p. 109.) have described cordierite produced in sandstones enclosed in basalitic rocks, or in contact with the latter. Ref. Lacroix: Le Gabbro du Pallet: Bull. Carte Geol. France. No. 67. (1899) p. 46.

currences had been reported in the entire series of basic igneous rocks in which the mineral was not demonstrably derived from cordierite preëxisting in some granite or gneiss, a portion of which had been torn from its place and enclosed in the eruptive rock at the time of its ascension.

The only known occurrence of cordierite in basic granitoid rocks was described a few months ago by M. A. Lacroix in his interesting memoir entitled "Le Gabbro du Pallet" (Bull. Carte Geol. France. No. 67. 1899). The cordierite here occurs in conditions very similar to those described above. That is to say, it is found in a noryte composed essentially of hypersthene, biotite, andesine, (often with oligoclase), magnetite, cordierite and pyrrhotite, with frequently quartz and garnet. The accessory minerals are apatite, graphite, zircon, spinel, sillimanite and staurolite(?). The cordierite is often very abundant, and usually accompanied by garnet and spinel. Occasionally the cordierite is wholly free of inclusions and twinning, but oftener both are present, and then pleochroic halos appear about the inclusions of zircon.

It is clearly demonstrated by Prof. Lacroix that the cordierite noryte of Pallet is the result of the absorption by a gabbro of an aluminous schist. This is shown not only from a study of the rocks mineralogically and chemically, but also from the field relations.

Several distinctions are to be noted between the cordierite noryte of Pallet, and that of Minnesota. First, and most important, is the fact that the Minnesota type is more basic, since it is an acid type of the labradoritic series while that of Pallet is an acid type of the andesitic group. Indeed, in the former the calcium oxide is notably in excess of the sodium, while in the latter the reverse is true. The Minnesota rock is therefore the most basic rock described hitherto, containing cordierite derived from the magma, since the two or three other occurrences described are relatively very potassic and acid. It contains bronzite (and enstatite) in place of the hypersthene found in the rock from Pallet, though the chemical composition shows slightly less magnesia, and fully as much ferrous iron. The biotite of the Minnesota type is of the unusual type anomite*, while in that from Pallet the mica is presumably

*The cordierite rock described by M. Max Koch contains phenocrysts of anomite.

normal biotite. Garnet and sillimanite have not been found in the cordierite noryte from Minnesota. Finally the hypersthene of the gabbros and norytes of Pallet is changed by amphibolization to the monoclinic type cummingtonite, while the bronzite of the Minnesota rock by the same process changes to the rhombic type anthophylllite. This change is very similar to that described by M. A. Lacroix in the noryte of Arvieu, but differs in that the original pyroxene in the latter case is negative hypersthene instead of positive bronzite.

It is well known that cordierite often contains pleochroic halos about minute included crystals of zircon. Such halos are found in the cordierite of the noryte of Pallet, described by Prof. Lacroix. In the Minnesota type, zircon causes halos in the anomite, but it has not yet been found enclosed by cordierite, which is wholly devoid of halos.

Origin. It is considered here that the cordierite noryte is an endomorphic form of the gabbro of the region. This is demonstrated by the field relations which have been described, but it is not less clearly proved by the mineralogical and chemical composition. The excess of alumina which gave birth to cordierite and biotite is evidence of the contact origin. since such an excess is practically unknown in basic rocks except as produced by absorption of aluminous elements. The cordierite, indeed, is a mineral, as previously stated, whose occurrence in basic rocks is wholly exceptional.

The presence of quartz indicates an acidity in the magma which could hardly be produced at the border of the mass by differentiation.

Finaly staurolite, epidote and spinel are minerals especially abundant in regions of contact, and in the metamorphic series. The probable presence of graphite, included within the staurolite, adds another mineral to this list of contact products.

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*A. Lacroix: Minéralogie de la France, I. p. 558.

(*To be continued.*)

PORES IN THE VENTRAL SAC OF FISTULATE CRINOIDS.

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It is matter for sincere rejoicing on the part of students of Crinoidea that Mr. Frank Springer has at last given proof of the correctness of Wachsmuth & Springer's statement that pores exist in the ventral sac of certain Inadunate crinoids.* Permit me to congratulate him on the clearness of his descriptions and the conclusiveness of much of his evidence. It appears to me that his proof applies to certain species referred by him to the genera *Decadocrinus*, *Aulocrinus*, *Scytalocrinus*, *Scaphiocrinus*, and *Parisocrinus*. These all have a dicyclic base, are all Inadunata, and, with the exception of *Parisocrinus*, are pinnulate Dendrocrinoidea closely allied to *Poteriocrinus*. As for the single representative of Parisocrinus, referred to *P. subramosus* M. & G., I must confess that I am quite unacquainted with any such species, and that I am unable to find the specific name under any Inadunate genus in the published writings of Miller & Gurley, including Miller's "N. American Geology & Palæontology" with its appendices. I have regarded *Parisocrinus* as a genus provided with a madreporite and closely allied to *Sphærocrinus*.† This view would not be quite consistent with the conclusions of Mr. Springer, and it seems probable that there is an error somewhere. Setting *Parisocrinus* aside for the present, I agree with Mr. Springer that pores of the kind now described by him may well have occurred in other genera allied to those mentioned above. But I also agree with him that this is "only conjecture, without present proof."

I ask you to publish this personal appreciation of Mr. Springer's paper, not merely because it is always a pleasure to acknowledge a definite advance in science, but because I regard this particular advance as due in some measure to my oft-repeated criticism of the assertions of Wachsmuth & Springer. My suggestions and objections may not always have been well founded, but no better justification of my former sceptical attitude could be desired than the fact that

**Amer. Geol.* XXVI, pp. 134–151, pl. vii; Sept., 1900.

†Treatise on Zoology, III, p. 173; London, 1900.

it has induced Mr. Springer to prepare and publish his excellent paper, which has removed many difficulties and placed the whole subject in a clearer light and on a firmer basis.

Here I should have liked to stop; but there are in my friend's paper many remarks that show me in an unenviable aspect, and make it appear that my scepticism was not justified and that my criticism was not kept "within its legitimate bounds." I deeply lament this feeling, and have already expressed to Mr. Springer my regret that it should have been aroused by any words of mine. In writing the paragraphs to which he objects, I was most anxious to combine courtesy and friendliness with a clear exposition of my doubts. It appears that I did not succeed, and an apology is therefore due to the surviving representative of Messrs. Wachsmuth & Springer.

This said, I would like to explain what my criticism was and why I still think that it was legitimate. I have never denied the existence of pores in any genera in which they are now proved to exist. Nor have I ever been prejudiced for or against their presence in one genus or another. On the contrary I have always looked for them and attempted to draw them in those specimens that circumstances have led me to study. The results of my investigation have been to show that certain definite appearances supposed to be pores were not really so, aud that pores did not exist in certain genera where their existence was either asserted or conjectured, or at least implied by the more general statement of eminent authorities. Mr. Springer (not to mention Lovén, Wachsmuth, and others) admits the accuracy of my observations, and therefore can not, without fresh evidence, venture to ascribe pores to *Cyathocrinus, Thenarocrinus, Botryocrinus, Euspirocrinus, Streptocrinus, Mastigocrinus, Gissocrinus,* "and possibly the Cyathocrinidæ generally." This is a considerable admission, and perhaps I should have been content to let the matter rest there. But when I came to examine the grounds on which Messrs. Wachsmuth & Springer continued to assert the existence of pores in other genera, nothing led me to suppose that they had before them structures of a totally different character to those which I had in-

vestigated. They made assertions, but as they gave no figures and no detailed description, I took the liberty of pointing out that authority could not supply the place of proof. Other naturalists of no less eminence had been misled, why not they also? Consequently when their great Monograph appeared I looked with expectancy for the descriptions and figures that should afford the desired evidence. Again I found an assertion—a very strong one it is true, but supported only by figures which hardly seemed to advance the case. The mere existence of dark spots, whether at the angles, at the sides, or in the substance, of a plate is, I still maintain, no proof of the existence of pores. A drawing, however accurate showing no more than do figures 2, 5, and 9 on pl. vii of the Monograph, is not to be accepted as evidence. Surely we might have been given figures such as 4, 16 and perhaps 8, of Mr. Springer's present paper, and so have been spared all future controversy.

Now as to the position of the pores and the correctness of the figures. I admit that I was quite wrong as to the actual position of the pores, but Mr. Springer's explanation of my mistake is more well-meant than well-founded. Had my mind been so warped as he supposes, I should hardly have figured and described appearances so similar to those found by him as are given in the "Crinoidea of Gotland, I" pl. i, f. 37, 49, pl. viii, f. 292, pl. ix, f. 322, 334 pl. x, f. 378. Some of these are not pores, others, I am now prepared to admit, may be. When Mr. Springer not unfairly remarks that I had seen the specimens of *Aulocrinus*, (a statement I am quite willing to accept, though I cannot confirm it) he forgets that, when I had the pleasure of spending a few days with Charles Wachsmuth and the privilege of seeing the Wachsmuth collection, my mind was very fully occupied in discussing all kinds of matters with our departed friend and in studying specimens of more immediate interest to me. I can hardly be expected to remember all the details of specimens that I saw for a few minutes more than seven years ago. The reasons that I had for supposing the pore-like appearances to lie at the angles of the plates, or at least between the chief radiating folds (axial folds), are two. First, the fact that the supposed pores described by Lovén

and others had turned out to be nothing but depressions lying between the folds, and that such appearances in a similar position were exceedingly common, and were correlated in many cases with the existence of articular surfaces on the edges of the raised folds as described and figured by me in *Mastigocrinus* and *Botryocrinus*. Pores and articular structures could not well coincide, but ligament-scars might easily be taken for pores. Mr. Springer chooses to regard my "few hundreds" as a rhetorical exaggeration; he will therefore be interested to learn that of Inadunate crinoids showing the ventral sac, there are over four dozen from a single horizon and locality in the British Museum alone, that the numbers in the Swedish State Museum are certainly larger, and are rivalled by those in the Woodwardian Museum at Cambridge, while I have also examined more specimens than I can remember in dozens of other museums. This being so I really cannot have my statements disputed "*in toto*," although I will no longer attempt to extend it to genera of which I have not made a special study. In fact I am now able to confirm Mr. Springer's statement as regards the position of certain appearances in some American species from my own observation.

But, why, it may be asked, was I formerly so ready to extend my conclusions to the specimens studied by Wachsmuth and Springer? The answer to this is my second reason. The first time that those acute and careful investigators alluded to these structures they wrote as follows: "The plates of the ventral sac in the *Cyathocrinidæ* are usually compartively large, rather thin, hexagonal pieces . . . . . The pores perforate the plate at each angle."* In "*Cyathocrinidæ*" they then included all Inadunata, and since they never, to my knowledge, withdrew this statement as to the pores being at the angles, I had no reason to suppose that "in the Poteriocrinidæ . . . without exception the position of the pores is the exact reverse of that stated by"—Wachsmuth & Springer. Further, they have never lost an opportunity of stating that the supposed pores are on the suture lines and "never penetrate the inner portions of the plates like the water pores of the Neocrinoidea." (See "Revision" III, p. 66, p. 83, and "Perisomic plates," p. 361). I cannot

find that they have ever modified this statement either, and indeed Mr. Springer appears to intend confirming it in his present paper. It is no doubt correct so far as present knowledge goes.

Since, then, these statements fully agreed with my own observations I was not a little surprised to find adduced as "most complete evidence" of pores passing through the plates, figures that not merely made no attempt to delineate the passage of the pores, but that showed the alleged pores in positions where their presence had never been asserted or had actually been denied. All this without one word of elucidation. What was one to suppose? The simplest explanation seemed to be that that the passage of the pores was, after all, too obscure a phenomenon to be shown; that the pores themselves were very difficult to see; and that the artist instructed to draw them had, therefore, in some instances inserted them in the wrong positions. Such an event is not uncommon, and if one points it out one is not generally considered to be accusing an author of misrepresentation, still less of wilful intent to deceive, I however, with no direct evidence at my command, merely "suggested" it as a possible explanation. Mr. Springer is so fairminded in debate and so zealous for the truth that he has felt it right to make admissions which show that my suggestions were not so far out after all. We need not reckon up the pores and see whether the balance of correctness is in my favour or his. Is it not enough justification for my suggestion that out of eight figures (2a, 2b, 4, 5, 7, 8, 9, 10a) showing pores, no less than five have an appreciable quantity incorrectly placed. Mr. Springer admits this for 2a, b, and 5; he does not seem to have noticed apparent pores at the angles of the plates in the distal region of fig. 4; as for 7 and 8, they may be absolutely correct drawings, but I should be sorry to have to infer the position of the pores from their evidence; the apparent pores in the cup and proximal portion of the sac of fig. 6 are unexplained; fig. 10a (*Coeliocrinus ventricosus*) is passed by without comment on page 134 of the paper before me, although the very clear appearances of pores must all be incorrect or deceptive according to the canon laid down on page 138 by Mr. Springer. There

*"Revision of the Palæocrinoidea" I, p. 9 of author's copy; 1879.

remains only fig. 9 (*Aulocrinus*) to give undoubted evidence as to the position of the pores. But how was anyone, in the absence of that special mention which Mr. Springer still finds so unnecessary, to judge between fig. 9 and fig. 10? To charge the authors with having told their artist to falsify any of the figures on their plate vii would not be a "serious" or "deadly" accusation; it would be mere childishness, for no one would intentionally publish figures that were mutually contradictory. But after reviewing the whole case in the light of the frank, lucid and exhaustive account now given to us by Mr. Springer, I can only repeat my opinion that some explanation of the differences from other figures and observations should have been given, and that in several respects scepticism has been more than justified.

SOME CURIOUS MATTERS ILLUSTRATIVE OF GEOLOGICAL PHENOMENA.

By B. K. Emerson, Amherst, Mass.

Plates XXI and XXII.

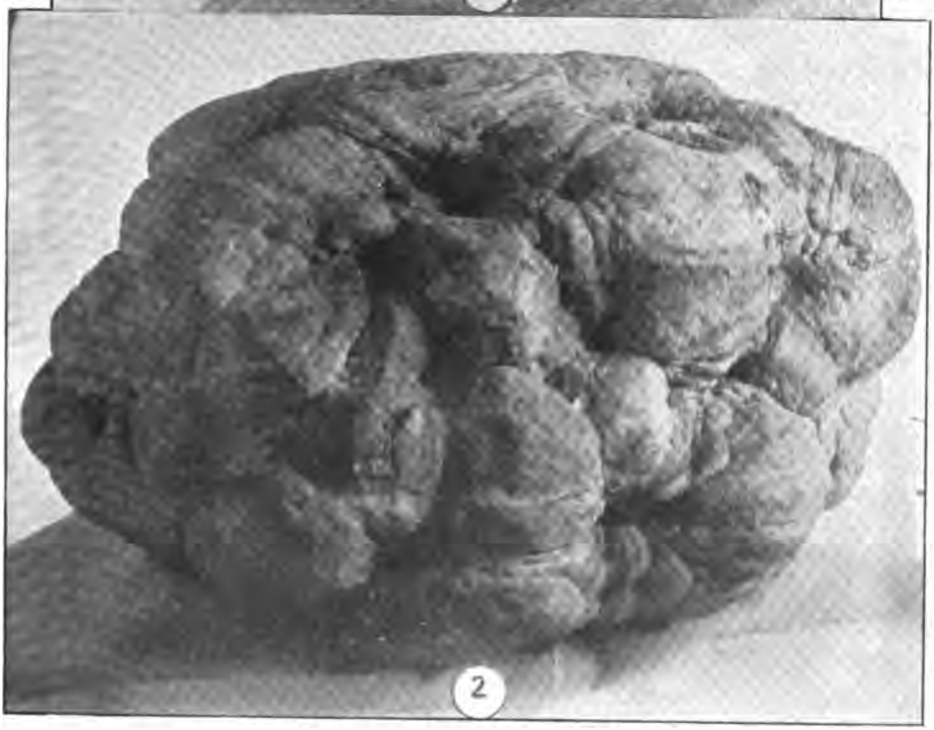
1 *The dependence of crystallization on character of surface.*

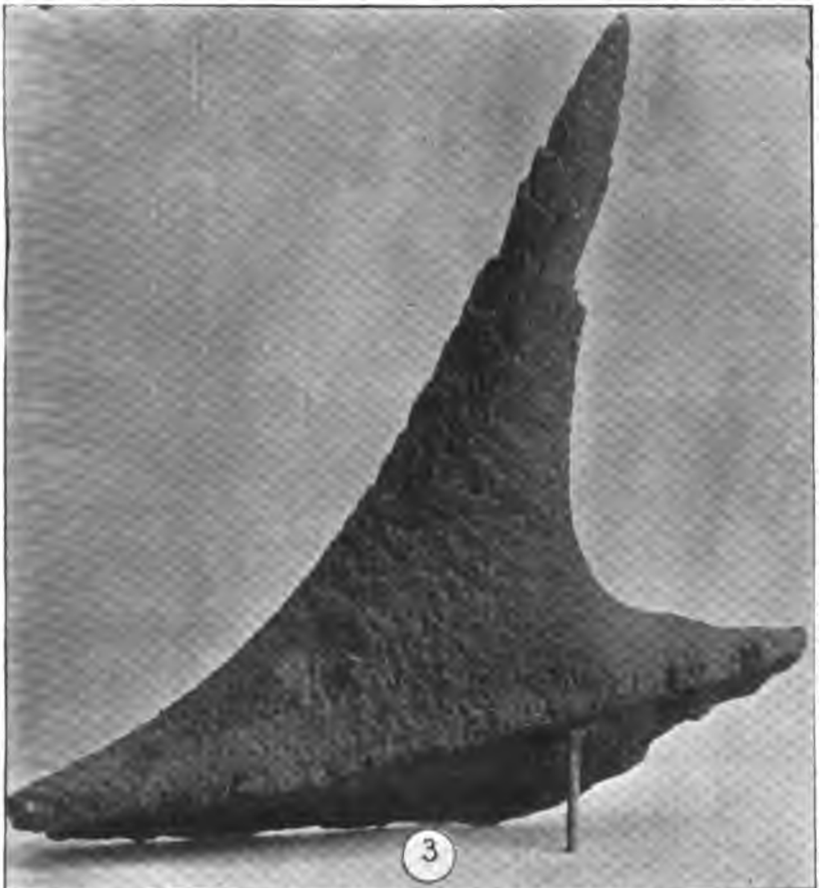
Figure 1.

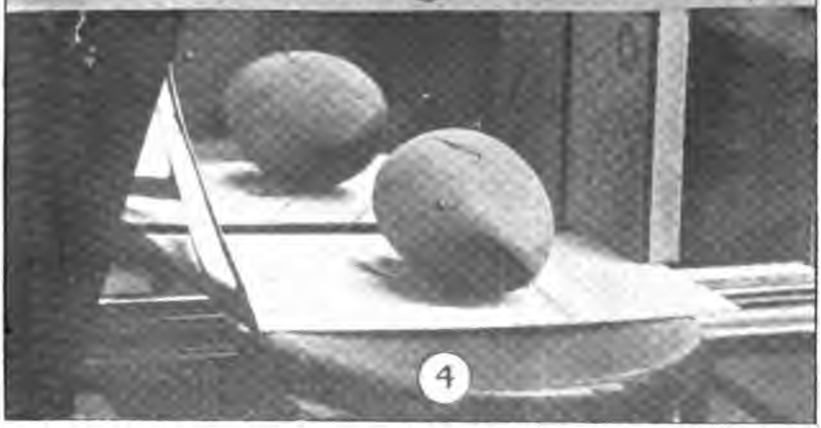
Many years ago when president Edward Hitchcock was professor of all the sciences in Amherst College, he had a laboratory in the cellar of the old chapel which was familiarly called Hades.

When the room was dismantled I found on a shelf a small bottle which had manifestly contained ammonium sulphide. The fluid had evaporated by capillary escape through the space between the neck of the bottle and the glass stopper and an incrustation of sulphur distinctly crystalline and thick enough to be yellow encircled the bottle about in the middle, showing the hight to which the fluid rose when it was last placed on the shelf. The upper half of the bottle between this ring and the bottom of the stopper was marked by two systems of concentric rings closely resembling the lemniscates of color in the polarization figure of a biaxial crystal. This was depicted on the inside of the glass by films of sulphur so thin as


1


2


3


4

to be white, which alternated with bands of corresponding width from which the sulphur was absent.

As one looks down on the bottle from above these rings are arranged symmetrically with regard to a median line analogous to the black band in the optical figure but the two axial centers are not placed in the line at right angles to this plane, but the two systems of rings sag symmetrically below this line. It is clear that this bottle was made by the old fashioned method of blowing, that the median plane separating the two systems of rings was the plane of junction of the halves of the wooden mould in which the clot of glass was blown to the shape of the bottle and that the glass chilled quickest along this line and became most viscid. The continued blowing then caused the glass to flow symmetrically in the two segments thus marked out by the lines of flow shown in the figure.

The flow was not directly outward but outward and downward, giving the sag in the figure described above, because the mould was placed on one side during the blowing or because one side of the mould was more open than the other.

As the glass flowed outwardly a rythmical difference of surface texture developed and the bands of rougher and smoother surface were drawn out into symmetrical rings. This difference of surface was brought out by the sulphur which was able to crystallize on only one of the surfaces, probably on the rougher one, in which the escape of heat or electricity from the irregularities may have favored crystallization. It is an illustration of what occurs so frequently in crystals, that faces of a given form will be incrusted and those of another avoided by the crystallization of a foreign body.

2. *A remarkable Geode.*

Figure 2.

Many years ago a missionary graduate sent to the geological museum of Amherst College, a great geode from the Orange river in South Africa, which is remarkable for its great size, the deep regular pittings like the eyes of a potato and rich translucent amber color and firm polish of its surface. It was 14 inches long and 10 inches high and 9½ thick.. I had many times taken a hammer with the intention of learning what was in the interior but desisted—the form was so perfect.

It was, a few years ago, sawed in two for me by the Chester Granite Co., and the interior was found to be a beautiful undulating coarse drusy surface of fine pale amethysts.

3. *An Emery and Iron Stalagmite.*

Figure 3.

The object figured had the shape of the thorn from a rose bush, which had been separated from the branch so that the base is concave from the shape of the twig on which it grew.

It was taken from an iron supporting rod beneath a high speed emery wheel in the United States Arsenal, at Springfield, used in polishing down some portion of a rifle barrel, and was formed at the point where a stream of sparks was directed against the cylindrical iron support of the machine.

Now and then a grain of emery torn off with a minute portion of highly heated iron attached, struck the point just so that the iron welded itself to the point of the stalactite-like form. This is more remote from ordinary geological processes than the others, but illustrates how the icicle or stalactite form depends on action concentrated on a growing point.

The point is seven inches long and has a curious concentric structure in cylinders which are almost separate from each other and which terminate in regular succession and thus produce the regular tapering form. They are so exceedingly thin and so entirely separate that several have broken away near the point, destroying the perfect symmetry of the original.

4. *Rythmical erosion.*

Figure 4.

Some years ago, a pebble of a medium grained red sandstone, an average brown stone, was brought me which had been taken from the bottom of a well, excavated in sandstone for the placing of a turbine wheel at the pistol shop in Hatfield, Mass.

The boulder has as perfect a surface as a sea beach pebble. It is 9 inches long and 3 wide in the thickest part. It is not known how long it had been in the narrow space between the wheel and the bottom of the well. It tapers at one end to a flat chisel-like edge, like that of an Indian adze, and narrows at the other to a similar edge which makes an angle of about

80° with the first. The crests from the corners of these terminal edges fade away gradually toward the center, which is nearly circular in cross section. The pebble is, as it were, a graphic solution of the equation of motion of the water in the confined space beneath the rapidly moving wheel.

The stone is (in the figure) placed in front of a mirror and the chisel edge in front, marked by a long pin, slopes from left above to right below, while the opposite direction of the rearward edge is shown by the opposite position of the other pin, and is seen in the image in the mirror, though here the shading could not be managed so as to bring out the regular adze-like edge of the stone, nor the symmetrical way in which the crests from the outer corners of the cutting edge pass into the general ellipsoidal shape of the central portion of the stone.

CERTAIN FAUNAL ASPECTS OF THE ORIGINAL KINDERHOOK.

By CHARLES R. KEYES, Des Moines, Iowa.

The original Kinderhook formation, as exposed along the upper Mississippi river has long been of special interest because holding a stratigraphic position on the division line of the Devonian and Carboniferous. On this account, also, the beds composing this terrane have been put first in one system and then in the other, until finally the uncertainty regarding their geological age has increased rather than diminished.

Until very recently* the correlations of the various sections with the typical Kinderhook have had to be inferred from imperfect fossil data. Certain peculiarities in the local stratigraphy have prevented parallelism of strata by visible continuity. For present requirements, with its refined methods, the available information has been too inexact to be of very much value. For the most part the fossils have to be studied anew in order to find out in just what layers the various forms occur. Only in this way can useful and exact comparisons of the fauna be made.

Already Weller has begun, along the lines indicated, a

*Journal Geology, Vol. VIII, pp. 315-321, 1900.

series of "Kinderhook Faunal Studies." Judging from the two installments already issued it is expected that there will soon be available much of the long desired information concerning the exact stratigraphic range of the fossils, and the biotic relationships of the various groups.

Except in a few instances, it cannot be gathered from the literature alone from just what horizons the fossils described from the Kinderhook were obtained. Nevertheless, some familiarity with the localities in which collectors have worked, and personal acquaintance with certain of the most active of the earlier investigators in this field, enable most of the horizons of previous workers to be accurately located. For example, Meek and Worthen's paper* on the reference of the so-called Chemung of the region, including the Chouteau, Vermicular and Lithographic beds of Missouri (their Kinderhook), to the Carboniferous instead of the Devonian, has its foundation chiefly in the fossils obtained at the town of Kinderhook, in beds near the top of Kinderhook formation, the beds which are now regarded as belonging to the Chouteau division, including also a few feet immediately beneath. With the exception of a few feet of the upper sandy portion, all that part of the section now called the Hannibal shales and the Louisiana limestone were not considered at all. They were simply included because the Chemung (Kinderhook) was regarded as a geological unit. At Burlington, also, the data used by these authors were derived from the yellow (Chonopectus) sandstone and the beds above.

Numerous other cases might be cited from this region in which broad generalizations were built up from very small foundations. Most of the discussions regarding the age and correlation of the beds of the region under consideration have been manifestly based upon data far too meager to be of much real service, or upon evidence that was not at all critical in its nature.

Moreover, modern stratigraphy rests upon grounds wholly different from what it did even a few years back. The exact position of a terrane in the general geological column is now not so important as the relative local position with reference to known associated formations. Faunal age also has ceased to be any longer a vital consideration to the geologist.

*Am. Jour. Sci., (III) Vol. XXXII, p. 228, 1861.

When he has found out what are the geological units or terranes, and their relations to one another, he cares little or nothing about what biotic age is assigned. He has in his possession the skeleton frame-work which he can, at his leisure, clothe with flesh and blood. No subsequent finding of "Devonian" fossils in one part, of "Carboniferous" forms, in another, or even "Tertiary" species underneath all will change the ascertained relative position of his units. The disputes in regard to exact "geological age," according to a standard that he no longer recognizes as infallible or essential, concern him little. If the question of "geological age" or rather "biotic age" is approximately satisfactory so much the better. If not, stratigraphic work can go on without interruption. Any questions as to this criterion, or that, are left for those who have more time than he to answer.

In geological correlation in general the tracing by visible continuity of the various terranes is the only absolute method of procedure. This ideal state of affairs is, in practice, quite limited in extent. Problems have usually to be worked out by other methods. The biotic methods have been widely used; but of late years more rapid and more certain results are obtained by other means.

Instead of placing entire reliance on one general method the stratigrapher follows chiefly the method best adapted to the local conditions. Consequently the old methods of lithological similarity and similarity of lithological sequence, when rightly applied, have a wider and more exact bearing in the solution of correlative problems than, for example, many comparisons of local faunas or floras.

In the consideration of the various members of what has been called the Kinderhook formation along the Mississippi river, opinion has always been divided as to whether the prevailing aspects of the faunas were Devonian or Carboniferous. Hall, who 40 years ago referred the beds in question, and the Burlington section in particular, to the Devonian, never found reason to give up this idea. In the main, however, and in the absence of any direct inquiry, the Kinderhook of the Mississippi river region has long remained as a part of the Carboniferous.

It was the unsatisfactory state of the problem that led re-

cently to a special inquiry* as to the actual stratigraphic range of the fossils of the Kinderhook in the neighborhood of the typical locality. It was an inquiry as to what the original Kinderhook rocks had to say for themselves regarding the faunas they carried, independently of those of any other section, and irrespective of any ascribed geological age. The inferences drawn from this investigation were:

(1). Faunally, the typical Kinderhook formation could not be regarded as a geological unit in the modern stratigraphical sense of the term.

(2). It contained two quite distinct general faunas, which are not genetically related; a lower one which reached to the top of the Hannibal shales, and an upper one, which nowhere went below the same horizon.

(3). The main part of the typical section was closely related faunally to the beds beneath; the upper part, to those above.

(4). If to-day we were to classify anew the typical Kinderhook and associated beds we would unite the upper beds, regarded as the equivalent of the Chouteau, with the Burlington.

Whether the lower fauna of the typical Kinderhook is to be regarded as a Devonian one or not, matters little in the present connection. That it is, as a whole, not related to the upper fauna is certain. That it is related, and related closely and genetically, to still lower faunas which it has been customary to regard as Devonian is equally certain. If these faunas under the typical Kinderhook are not Devonian, then there is surely no Devonian fauna represented at the type locality of the Kinderhook, and at Louisiana.

In the case of the Burlington section, 125 miles north of Louisiana, the conditions are somewhat complicated. There exist factors which have no representation farther south, and which are, at first, likely to confuse one in attempting to parallel the two sections. Among other things, these peculiarities at the northern locality have led Worthen, White, and very recently Weller, to believe that the Fragmental, or Productal limestone, 15 feet beneath the base of the Burlington limestone, is the northward extension of the Louisiana limestone.

Concerning this opinion the recent statements of Weller†

*Proc. Iowa Acad. Sci., Vol. IV, pp. 26-49, 1897.

†Trans. Acad. Sci., St. Louis, Vol. X, p. 124, 1900.

are of interest. He says: "If it be true tnat bed No. 4 is the northern extension of the Louisiana limestone, then the Chonopectus sandstone and the underlying shales would be included in the Devonian according to Keyes' interpretation of the Kinderhook."

Now "bed No. 4" is the Productal limestone. It is above what in the Iowa and Missouri reports has been regarded as the Hannibal shale, and if the most recent and detailed stratigraphical evidence* is to be relied upon, it is very near the top of the Kinderhook, instead of at the very base of that formation. According to the statement just quoted, the Chonopectus sandstone, which immediately underlies the Productal limestone or is separated from it only by a very thin Coralline zone, would then be parallelled with the shales underlying the basal member of the Kinderhook (or Louisiana limestone), at the type locality of that formation. However, there are grave difficulties to overcome before this opinion is fully substantiated, and Weller refers specifically to no data from which his inferences are drawn.

Concerning the geological position of the Chonopectus fauna alone Weller farther remarks: "Taken as a whole a large number of the total 81 species recognized in the fauna, have Devonian and not Carboniferous relationships, but this is not sufficient evidence upon which to establish the Devonian age of the fauna. In general, in paleontologic interpretation, the initiation of a new invertebrate faunal element is of greater importance than the holding over of a much larger element from an older fauna, and on this principle the strongly Carboniferous element among the brachiopods of the Chonopectus sandstone is to be considered as weightier evidence than the holdover pelecypods and cephalopods."†

Of the six zoological classes of organisms, which the 81 enumerated species go to make up, all but the brachiopods have admittedly a strong Devonian aspect. Of the score of brachiopod species one-half are certainly indecisive as to exact age, and of the other half there is about equal division between Carboniferous and Devonian types. There is therefore

*Journal Geology, Vol. VIII, p. 317, 1900.
†Trans. Acad. Sci., St. Louis, Vol. IX, p. 126, 1900.

one-fourth of the brachiopods that might be considered as forming a new faunal element.

The importance of the introduction of a newer, or geologically younger faunal element is fully recognized, but it is not believed that its appearance should entirely overbalance the existence of greatly predominating older elements. We can hardly consider a new faunal age to begin with every initial introduction of a new faunal element. Faunas have their beginnings far down in the depths of older faunas. They expand, displace the older elements and culminate. They decline and fade away far up among still newer faunas. We have analogous examples in the progress of nations. The initiation of a new element does not indicate a new dynasty. A new political movement has its birth midst a multitude of conflicting elements. It may grow in importance and finally displace the existing government. Only when it has overcome the older ruling powers is a new régime inaugurated. Not until then does the nation require a new name. There are long steps between the initiation of a new element and the initiation of a new régime.

If a new régime, a Carboniferous régime, is initiated at the basal horizon of the Louisiana limestone the actual evidence afforded by the 81 species enumerated from the Chonopectus sandstone, which is regarded as pre-Louisianan in age,* appears to be far from demonstrating it. The consideration of the other and related faunas may give more substantial proofs. However, on this point it is probably best to suspend judgment until the "Faunal Kinderhook Studies" now in progress are completed, since for the first time evidence along these lines promises to be exhaustive.

The still later statement in which Weller* regards all of the Burlington section below the Productal limestone, (Bed No. 4) as older than the Louisiana limestone, suggests another interesting consideration. The inference is that this writer considers the most marked faunal change to take place at the base of the Productal limestone. If the view I have already expressed be the correct one, that this horizon at Burlington is to be considerd as equivalent to the base of the Chouteau limestone farther south at Louisiana, as the stratigraphy seems

*Iowa Geol. Sur., Vol. X, p. 79, 1900.

†Loc. cit.

clearly to indicate, and not the base of the Louisiana limestone, then there is perfect agreement in Weller's conclusions regarding the most notable faunal change in the Burlington section and my own in the Louisiana section taking place at the same horizon.

In regard to the lithological character of the Productal limestone at Burlington being the same as those of the Louisiana limestone the real resemblance is certainly very remote. Few would ascribe lithographic properties to it as in the case of the Louisiana stone. While at Burlington it is the only bed the general appearance of which at all approaches the Lithographic or Louisiana limestone there is not very much to suggest identity. If the two limestones are one and the same there must be very remarkable and wholly anomalous stratigraphical phenomena existing between the cities of Keokuk and Burlington.

There is one feature in which Mr. Weller's recent work corroberates my own results in a most conclusive manner. Kinderhook as a geological title is no longer available and valid.

If the Chonopectus sandstone immediately beneath the Productal or Fragmental limestone at Burlington is pre-Louisianan in age, as Weller suggests, it is ascribing an age much older than is even intimated in any of the recent Missouri and Iowa reports.

In this connection certain recent records of deep wells are not without interest, in attempting to parallel the Burlington section with that of Kinderhook and Louisiana.* The evidence derived indicates that the lowermost member of the typical Kinderhook, the Louisiana limestone, which is 60 feet thick at the type locality, gets thinner and thinner northward until at Keokuk it is not more than 10 feet thick, and doubtless fades out altogether before Burlington is reached. On the other hand the median member of the Kinderhook, the Hannibal shale which is 70 feet thick at the type locality retains its full thickness at least as far north as Keokuk, and at Burlington appears to merge downward with the shale which farther south underlies the Louisiana limestone.

The latest faunal correlation appears to be closely in agreement with this stratigraphical interpretation.

*Journal Geology, Vol. VIII, p. 317, 1900.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

A Contribution to the Geology of the Northern Black Hills. Thesis Submitted in Partial Fullfillment of the Requirements for the Degree of Doctor of Philosophy, in the Faculty of Pure Science, Columbia University, June 1899. By JOHN DUER IRVING. [Annals N. Y. Acad. Sc. Vol. XII, No. 9, pp. 187-340, pls. V-XVI, figures 5-20.]

This paper constitutes a valuable addition to the geology of the Black hills. Its purpose is the extension of stratigraphic and petrographic detail rather than the development of new theoretical knowledge. The district described exhibits most strikingly many phenomena whose origin is due to the vast intrusive masses which form the predominating rock of the region.

The Black hills topography strikingly illustrates the relation of degradation to geological structure. In the western area the country rock consists of horizontal Carboniferous strata; in the plateau which these strata form streams have cut precipitous canyons, leaving flat table-like divides. Farther east the topography consists of the conical hills and sharp irregular ridges with complicated drainage, characteristic of regions which have been the seat of igneous activity.

Dr. Irving finds Algonkian, Cambrian and Carboniferous beds, containing many intrusions. The character of the intrusion is found to be dependent upon the nature of the rock into which it is intruded;—in the vertical slates and schists of the Algonkian only dikes are found; in the soft thinly bedded Cambrian shales, are sheets; the massive Carboniferous sandstones and limestones are penetrated by very few dikes and by some irregular masses which Dr. Irving regards as belonging to none of the ordinary classes of intrusion. In each case the intrusion has followed the direction of least resistance and subsequent erosion has left the dikes standing out as ridges and the sheets as laccoliths.

Petrographically the intrusives are found to present a large variety of types. The most abundant are the various kinds of phonolyte which constitute the greater number of the laccoliths. Various types of rhyolytes, andesytes, dacytes, diorytes, lamprophyric dike rocks and amphibolytes are found. The Black hills have at least twice been the seat of prolonged igneous activity. The first period was previous to the metamorphism of the Algonkian and was characterized by the intrusion of sheets of basic rock, now represented by the amphibolytes. These intrusives were metamorphosed with the Algonkian strata, and together they were raised to a vertical position, hence the sheets now appear to be dikes. The second period of activity was post-Cretaceous and was marked by a highly alkaline series of intrusions. This series forms true dikes in the Algonkian and sheets in the Cambrian. It yet remains to be determined whether the lamprophyric dike rock (augite-vogesite) represents the final

basic residuum of the alkaline magma, or whether it belongs together with the phonolytes and quartz-ægirite rocks, to a different series from the rhyolyte-andesyte rocks.

In the district described gold occurs in the Algonkian, Cambrian, and Carboniferous, and in placers of recent formation. It occurs associated with pyrite; in quartz veins with silver and lead; and free. Silver is also found.

Dr. Irving has covered only a portion of the region affected by the Black hills intrusions. In this field he has confined himself to description and to the farther elaboration of previously formulated hypotheses. The differentiation of rock magmas is a subject for which, as Mr. Irving himself states, this region is admirably calculated to provide data. This problem has been barely touched by him and it is to be hoped that additional data may be found from farther investigation of the Black hills and of the Bear Lodge mountains. When such investigation takes place Dr. Irving's determinations will be of undoubted value. I. H. O.

The Moraines of Southeastern South Dakota and their Attendant Deposits; by JAMES E. TODD, U. S. G. S. Bull. 158, pp. 1–168.

This volume is a preliminary report, treating of a relatively small portion of the Dakota loop of the great moraine. It furnishes valuable data upon several Pleistocene problems;—the origin of loess, the distribution of glacial drift, and post-Pliocene oscillations of the earth's crust. The greater part of the report is descriptive of glacial deposits in South Dakota and Nebraska. Two moraines are found, the outer one which extends to the Missouri river, marking the maximum extent of the ice in the second glacial epoch. Outside of this moraine deposits of a previous epoch are found; of these deposits loess is the most abundant. Mr. Todd discusses the formation of loess, believing it here to be of fluvio-lacustrine origin. The inner moraine represents a halt in the retreating ice and is much less prominent than the outer. Inside the second moraine is the flat of lake Dakota. Mr. Todd discusses the age of the trough of the Missouri river, and concludes that the evidence is in favor of a post glacial excavation. I. H. O.

Elements of Mineralogy, Crystallography, and Blowpipe Analysis, from a Practical Standpoint, including a description of all common or useful minerals, with tests necessary for their identification, the recognition and measurement of their crystals, and a concise statement of their uses in the arts. By ALFRED J. MOSES and CHARLES LATHROP PARSONS. Octavo 414 pages, 664 cuts, new enlarged edition, $2.00, New York, 1900, D. Van Nostrand Company.

The title describes this book fully. It is one of the interesting and valuable series of the science faculty of the School of Mines of Columbia University, New York, although, in this instance, Prof. Parsons is of New Hampshire College, Durham, N. H. Its design is for the student of the technical school and for all courses in mineralogy where mineralogy

is taught practically rather than by lectures. It will also serve as a vademecum for all amateurs and explorers whenever they are interested in the minerals most commonly met. It pre-supposes, however, that the student have access to such physical instruments or] chemical reagents as will carry out the tests required. The elements of all mineralogy, both chemical and physical, are here embraced. It is difficult to see how it could be improved, either in matter or method, unless it be in the use of the Miller system exclusively, for the nomenclature of crystals. N. H. W.

A Handbook of Rocks, for use without the microscope. J. F. KEMP; *with a glossary of the names of rocks and of other lithological terms.* Second edition, revised, pp. 185, $1.50. D. Van Norstrand Company, New York, 1900.

This convenient handbook is here improved by the correction of some errors in the first edition, and the enlargement of the glossary of names of rocks. It embodies the results of wide study and evinces great familiarity with geological literature. Its generalizations are usually exact and discreet, but are occasionally, though perhaps not injuriously, shaded by the personal bias of the author. N. H. W.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Beyer, S. W.

Geology of Hardin county. (Geol. Sur. Iowa, vol. 10, pp. 221-313, 1900.)

Beyer, S. W.

Mineral production of Iowa in 1899. (Geol. Sur. Iowa, vol. 10, pp. 45-58, 1900.)

Blake, W. P.

Remains of the Mammoth in Arizona. (Am. Geol., vol. 26, p. 257, Oct., 1900.)

Branner, J. C.

Two characteristic geologic sections on northeast coast of Brazil. (Proc. Wash. Acad. Sci., vol. 2, pp. 185-201. Aug. 20, 1900.)

Branner, J. C.

The origin of beach cusps. (Jour. Geol., vol. 8, pp. 481-484, Sept.-Oct., 1900.)

Buckley, E. R.

Results of tests of Wisconsin building stones, III. (Jour. Geol., vol. 8, pp. 526-567, plates. Sept.-Oct., 1900.)

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology, and mineralogy.

Calvin, S.

Iowa Geological Survey, volume 10; annual report, 1899, with accompanying papers, pp. 666. Ten maps, 102 figures. Des Moines. 1900.)

[Edward Drinker Cope.]

Addresses by Theo. Gill, H. F. Osborn and Wm. B. Scott. (Proc. Am. Phil. Soc. Phil.; memorial volume I, pp. 273-314. 1900.)

Crawford J.

Dr. Angelo Heilprin and the decrease of water in lake Nicaragua. (Am. Geol., vol. 26, p. 257, Oct., 1900.)

Davis, C. A.

A contribution to the natural history of marl. (Jour. Geol., vol. 8, pp. 485-497, Sept.-Oct., 1900.)

Davis, C. A.

A remarkable marl lake. (Jour. Geol., vol. 8, pp. 498-503, Sept.-Oct., 1900.)

Davis, W. M.

Notes on the Colorado canyon district. (Am. Jour. Sci., vol. 10, pp. 251-259, Oct., 1900.)

Douglas, James

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PERSONAL AND SCIENTIFIC NEWS.

Dr. Heinrich Ries, of Cornell University has recently returned from Europe where he spent four months, attending the Geological Congress, and also visiting many mining regions in Spain, France, Germany, and the Balkan countries.

Dr. George H. Ashley, of the Indiana geological survey, has been appointed professor of natural history at the college of Charleston, in South Carolina.

Dr. E. C. E. Lord has been appointed assistant in mineralogy and petrography at Harvard University, in place of Dr. A. S. Eakle, lately instructor there.

Prof. G. F. Wright, who with his son Fred B. Wright is on a tour round the world, may be expected to return to Oberlin, according to the program outlined at the start, notwithstanding delay in China and Manchuria by reason of the recent Boxer uprising.

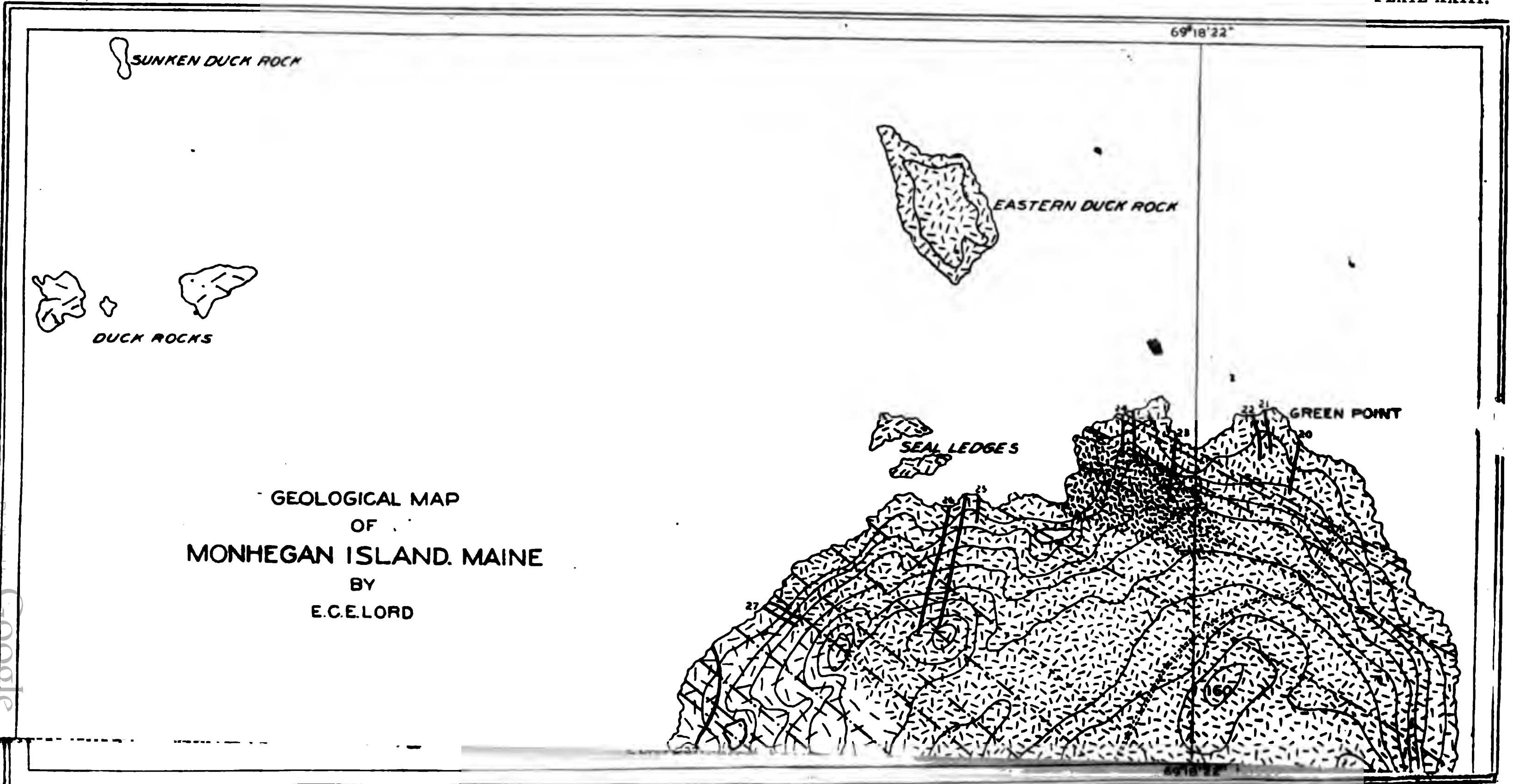
Dr. A. W. Grabau has been appointed instructor in geology at Tufts College, Somerville, Mass. This is in addition to the position at Reusselaer Polytechnic Institute, Troy, N. Y., the two institutions having their geological courses in different halves of the school year.

Occasional Papers of the Boston Society of Natural History, vol. iv, part 3 has been ready for distribution since August last, but for some reason had not been sent to the members up to Nov. 1st. It consists of Prof W. O. Crosby's paper on the Blue hills portion of the Boston basin, one by Dr. Grabau on lake Bouvé, and one by the same author on the paleontology of the Cambrian terranes of the Boston basin.

A pleasant plan of visits was inaugurated on Oct. 26 and 27, when a party of Yale University geological students and Dr. Gregory went to Cambridge. Friday afternoon was spent in an excursion to the Neponset river valley and the Blue hills of Milton, and the evening in an informal social gathering, with the instructors and advanced students of the division of geology of Harvard University. On Saturday an all-day trip was taken to the north shore, from Beach bluff to Marblehead, under the guidance of Prof. Wolff, to see the points of special petrographic and dynamic interest. A return visit to New Haven is planned for the middle of November.

The George Huntington Williams Memorial Lectures on the Principles of Geology. It is proposed to begin the publication of these lectures at at an early date. Two volumes are in preparation and it is anticipated that others will be published later. Vol. I is entitled "The Founders of Geology," by Sir Archibald Geikie, and Vol. II contains lectures by Prof. W. C. Brögger on the principles of a genetic classification of the igneous rocks and on the late geological history of Scandinavia as shown by changes of level and climate since the close of the Glacial epoch. It is proposed to limit the edition of these volumes as nearly as possible to the number of subscriptions received. Subscriptions ($2.00 per volume) should be sent to The Geological Department, Johns Hopkins University, Baltimore, Md..

PLATE XXIII.



GEOLOGICAL MAP
OF
MONHEGAN ISLAND. MAINE
BY
E.C.E. LORD

THE
AMERICAN GEOLOGIST.

VOL. XXVI. DECEMBER, 1900. No. 6

NOTES ON THE GEOLOGY AND PETROGRAPHY OF MONHEGAN ISLAND, MAINE.*

By E. C. E. LORD, Washington, D. C.

Plate XXIII.

Monhegan is the most important member of a small group of islands, situated within the depressed coastal area of Maine, about 10 miles to the south of Saint George peninsula and 12½ miles almost due east of Book Bay harbor.

The group may be considered geologically as a dissected plutonic mass forming a part of the Acadian province outlined by professor Dana† in his publications on the Archæan axis of North America.

The orographic movements resulting in the submergence and re-elevation of the Maine coast have been carefully recorded by Prof. Shaler in his study of the geology of Mount Desert,‡ and some of his observations may be duplicated, on a smaller scale, in tracing the geologic history of Monhegan. Thus we find, at various elevations marine benches and water worn caves marking periodic changes of sea-level. It seems improbable, however, judging from the present work of the

*The writer wishes to acknowledge his indebtedness to the authorities of the United States National Museum for kindly allowing him the opportunity to work up the material. He is especially indebted to Prof. Geo. P. Merrill, head curator, Dept. of Geology in the Museum for the privilege of studying the collections, and to Mr. Geo. C. Curtis, of Cambridge, Mass., for valuable suggestions concerning the physiography of the island.

†Bull. Geol. Soc. Amer., Vol. 7, p. 36 and Amer. Jour. Sci. (3rd series), Vol. 39, p. 378.

‡8th Annual Rep't U. S. G. S., 1887, p. 993.

waves, which is simply that of cutting back the salients, and slightly modifying the re-entrant features of the coast, that the topography of the island is to any great extent, the result of marine erosion.

Monhegan Island is of rectangular shape, measuring about 1¾ miles in length, by 3-5 of a mile in width. The smaller members of the group (Manana, Duck Rock, etc.) lie to the west of Monhegan and have with it a N. E.-S. W. trend, corresponding with that of the continental coast-line.

The topography of the group, as seen by the accompanying geologic map* is clearly that of a highly glaciated region but slightly modified by marine encroachment.

A very striking feature and one not hitherto noted on other islands in this vicinity, is the bold relief of the eastern headlands which rise almost perpendicularly to a hight of more than 150 feet above sea-level, thus producing coastal features of great scenic beauty and grandeur. These elevations with their broad and rounded summits and gentle slopes landward, extend in an E-W direction, across the island, broadening out and gradually falling away to the western coast-line. They are separated by low, broad valleys, or by irregular, basin-shaped depressions in which surface waters collect to form small ponds and marshes.

It is of interest to note that these valleys are almost at right angles to the direction of the ice-flow, which, as imperfectly indicated by glacial groves and markings is but a few degrees east of north. This main ice-movement has resulted in the excavation of the channel separating Manana island from Monhegan, as well as of the minor longitudinal gorges so common on the island. No direct evidence of glaciation was observed in the broad transverse depressions, owing to the abundance of vegetation, but it seems probable, judging by their peculiar form and the occurrence of erratic bowlders in them, that they were produced by ice-currents moving in an easterly direction across the island, along lines of structural weakness in the underlying rock.

Since the withdrawal of the ice-sheet marine erosion has

*This map is based upon a reproduction from an enlarged and corrected copy of sheet No. 312 of the U. S. Coast and Geodetic Survey prepared by Mr. Geo. C. Curtis, of Cambridge, Mass., and kindly placed at the disposal of the author.

essentially denuded the islands of all transported material, excepting the larger bowlders and small areas (left open on the map) of ré-assorted drift at the head of sheltered inlets.

Apart from the secular movements already noted the region has undergone excessive orographic disturbances, resulting in longitudinal and transverse faulting, as well as in a complex system of both vertical and horizontal jointing. The effect of crushing is also plainly seen in the minute fractures and rifts common in almost every hand specimen.

An important fracture extending through the northern end of Manana island in a N. 55° E direction across Monhegan forms a marked topographical feature of both islands. Excessive shearing in this direction has rendered the rock in the vicinity of Manana harbor semi-schistose, or produced a highly brecciated structure (western slopes of Light House hill).

The E-W faulting is not so extensive as the longitudinal, and plainly noticeable only in the neighborhood of the transverse depressions mentioned above.

One other important line of movement, possibly of more recent date than those already mentioned, extends in a N 55°-60° W. direction, corresponding exactly with the strike of a series of granitic dikes to be discussed later.

Although varying considerably in mineral composition the Monhegan mass, as a whole, consists of a coarse grained olivine-noryte, very rich in feldspar, and resembling, in part, at least, the olivine bearing anorthosyte of the Saguenay District, Canada.*

While this rock is quite common in New Hampshire, and eastern New York,† its exact equivalent has not hitherto been found in Maine, although the gabbroitic-diabase (black granite) occurring on St. George peninsula, Addison Point and

*See F. D. Adams; Amer. Jour. Sci., Vol. 50. 1895, p. 58; and Ann. Rep't. Geol. Sur. Canada, Vol. VIII, (J) 1895, p. 91.

†See G. W. Hawes; Geology of New Hampshire, Vol. III (Lithology) p. 168-169; G. H. Williams: The Gabbros and Diorites of the "Cortlandt Series," on the Hudson River near Peekskill, N. Y., Amer. Jour. Sci., Vol. XXXV, Feb. 1888, p. 438; ibid. Vol. XXXII, 1886, pp. 26-41; C. H. Symth, Jr.: On Gabbros in the South Western Adirondack Region. Amer. Jour. Sci., III. Vol. 40, 1894, p. 55, and Bull. Geol. Soc. America, No. 6. 1894-5, p. 261; J. F. Kemp: Gabbros on the Western shore of Lake Champlain, N. Y. Geol. Soc. Amer., Bull., Vol. 5, p. 213.

Vinal Haven,* resembles it very closely in mineral composition and may well be allied genetically.

The Monhegan rock is of granitoid structure, and varies in color from purplish gray to steel gray, with frequently a greenish tinge, due to the prevalence of secondary green amphibole. Weathered surfaces, are grayish brown, and present frequently a pitted appearance, owing to the more rapid decomposition of the feldspar.

The mineral constituents most readily discernible with the naked eye are feldspar, olivine, pyroxene and hornblende; which under the microscope are seen to be in the following proportions: plagioclase (50-90 %) > olivine > hypersthene > magnetite > diallage > hornblende. Fluctuations in the relative proportions of the ferro-magnesian constituents give rise to the subordinate types: troctolyte, noryte, olivine-gabbro and gabbro proper. These types represent slight phasal differences in the noritic magma, and are so intimately associated that no distinctive lines could be drawn between them in the field. They pass by gradual transition into hornblende-gabbro and gabbro-dioryte, which occupies a more limited area at the northern end of the island. Here the rock loses to some extent its gabbroitic character, being in part of finer grain and variegated color, owing to irregular inclusions of a quartz-bearing, light gray dioryte.

The petrographic continuity of the Monhegan mass is frequently interrupted by very coarse grained mineral segregations (Schlicren Gänge), and by a series of acid and basic dikes which will be discussed in a later chapter.

Of the minerals composing the olivine-noryte and allied rock-types, feldspar is by far the most important. It is of allotriomorphic development, in keeping with the granitic-granular structure of the rock. The irregular, stout, tabular crystals vary in length from two to ten mm and in breadth from one to five mm, and show in polarized light well developed polysynthetic twinning after the albite and pericline laws. Many of these composite individuals are, furthermore, united in accordance with the Karlsbader law.

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*See G. P. Merrill: Proc. of the U. S. Nat. Museum, Vol. VI, No. 12, 1883; S. E. Dickerman and M. E. Wadsworth: On Olivine Bearing Diabase from St. George, Me., Proc. Bost. Soc. Nat. Hist., Vol. XXIII, p. 28; G. O. Smith: The Geology of the Fox Islands, Me. Dissert. Inaug. Johns Hopkins University, 1896, pp. 61-63.

The crystals cleave readily parallel P (001) and M (010), and show on these faces average extinction angles of about 24 and 33 degrees respectively. They have a specific gravity of 2.72, which, with the properties already given. would identify them as bytownite (Ab, An_6).

The rather high specific gravity (Ab An_6=2.71 normally) may be partially due to abundant inclusions, which frequently occur in such numbers as to render the crystals almost opaque in transmitted light, and gives them a purplish gray color and sub-metallic luster.

These inclusions are either in the form of a fine, ferritic dust or of delicate needles arranged according to crystallographic directions in the feldspar (parallel $\breve{a}$ $\bar{b}$ $\dot{c}$) very like those described by Chester.*

The bytownite decomposes readily to calcite and kaolin.

The chemical analysis of this feldspar (I) compared with one of bytownite from Mount Hope, Md. (II)† shows a remarkable coincidence in composition. It also differs but slightly from the theoretical composition calculated by Schuster (Miner. and petrog. Mitth., III. p. 153 1881) for a mixture of six anorthite molecules with one of albite (III).

	I	II	III
SiO_2	48.06	46.17	46.5
Al_2O_3	32.54	35.22	34.6
CaO	17.51	16.29	17.3
Na_2O	1.77	2.31	1.6
Total	99.88	100.00	100.00

The next mineral in order of importance is olivine. It is in varying proportions in the olivine-gabbro and noryte, and forms the sole ferro-magnesian component of the troctolyte. It is perfectly colorless and occurs in the form of irregular, allotriomorphic grains common to basic plutonics. In many specimens cleavage parallel (010) and (100) is well developed, and not infrequently the crystals are intersected by microscopic fracture planes along which magnetite is extensively developed.

*F. D. Chester: The Gabbros and Associated Rocks in Delaware. Bull. 59 U. S. Geol. Survey, p. 13-14.

†See G. H. Williams: The Gabbros and Hornblende Rocks, occuring in the Neighborhood of Baltimore, Md.; Bull. No. 28, U. S. Geol. Survey, p. 20.

Inclusions of magnetite, pyroxene and feldspar are very numerous.

The olivine decomposes readily to serpentine and brown iron ore, and is in many instances surrounded, or entirely replaced, by secondary growths of amphibole, chlorite and mica. These secondary products are characteristic of feldspathic gabbros and norytes wherever olivine is in direct contact with a basic plagioclase, and have been variously interpreted.*

It seems probable in the case of the Monhegan norytes that they are due to the effects of regional metamorphism rather than to magmatic corrosion. Where metamorphism is not so far advanced as to destroy the original structure of the rock, the olivine is seen to be separated from the bytownite by three distinct mineral zones. The inner zone adjoining the olivine is about $\frac{1}{10}$ mm wide, and consists of tremolite prismatically developed normal to the surface of the olivine; the crude prisms are perfectly colorless and extinguish at an angle ($c:\mathfrak{c}$) of about 18°. Following this zone occurs a very narrow one (.05-.1 mm.) of a colorless, or pale green slightly pleochroitic

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*See A. E. Tornebohm: Uber die wichtigsten Diabas und Gabbrogesteine Schwedens, L. J. 1877, p. 383.

Fried. Becke. Eruptivgesteine aus der Gneissformation des oesterteichischen Waldviertels. T. M. P. M., 1882, IV, pp. 352-65, and Gestiene der Columbretes. Min. und Pet. Mitth., Vol. 16, 1896, pp. 327-336.

A. Lacroix: Contributions à l'etude des gneiss à pyroxene et des roches à wernerite. Bull. Soc. min. Fr., 1889, p. 245.

G. H. Williams: The Peridotites of the Cortlandt Series on the Hudson River near Peekskill, N. Y. Amer. Jour. Sci., 1886, Vol. XXXI, p. 35, and Bull. U. S. G. S., No. 28, p. 25.

W. S. Bayley: Fibrous Intergrowths of Augite and Plagioclase in a Minnesota Gabbro. Amer. Jour. Sci., Series III, Vol. 43, 1892, pp. 516-520.

H. B. Patton: Microscopic Study of some Michigan Rocks. Rep't State Board of Geol. Survey for 1891-92, p. 186.

F. D. Adams: Uber das Norian und Ober-Laurentian von Canada. L. J. B-B. VIII, 1893, pp. 466-470.

J. F. Kemp: op. cit., p. 221.

W. D. Matthews: The Intrusive Rocks of St. John N. B. Trans. N. Y. Acad. Sci., Vol. XIII, 1894, pp. 198-201.

H. Rosenbusch: Micros. Physiog. II, 1896, p. 315.

R. W. Schaefer: Die basische Gestiene von Ivrea. Min. und pet. Mitth., Vol. 17, 1898 pp. 495-517.

J. M. Clements: A Study of Some Examples of Rock Variation. Jour. of Geol., Vol. 6, 1898, pp. 384-386.

A. H. Elftman: The Geology of the Keweenawan Area in Northeastern Minnesota (III). Am. Geol., vol. XXII, Sept., 1898, p. 139.

mineral resembling chlorite, which terminates abruptly in an outer fringe of bluish-green actinolitic hornblende. This outer zone is usually from $\frac{1}{10}$-1 mm. thick and is formed of a dense interlocking mass of actinolite fibers. In many specimens, where the effects of orogenetic processes are more apparent, actinolite needles extend out in all directions, frequently wholly replacing the feldspar.

The actinolite is strongly pleochroitic (parallel $\mathfrak{c}$=bluish green, parallel $\mathfrak{b}$=grass green, parallel $\mathfrak{a}$=pale yellow) and shows on prismadic sections a maximum extinction of 22° (c:$\mathfrak{c}$ =22°).

In many cases the olivine is itself altered to a pilitic* mass consisting of fibrous tremolite, actinolite, chlorite and flakes of brown mica.

The olivine is normally the first ferro-magnesian constituent to crystallize, but it was found in some sections to contain large feldspar inclusions indicating a later period of crystallization. These inclusions are surrounded by rims of secondary hornblende and chlorite identical with those formed on the outer contact with the olivine, thus indicating that the minerals of both zones are of similar origin, and formed after the rock magma had reached a state of solidity.

Hypersthene is a constant accompaniment of the olivine in the Monhegan norytes. It occurs, either in the form of irregular grains, often surrounding the olivine, or as well developed crystals evenly distributed through the rock. The granules are in some instances associated with the olivine in such a manner as to suggest a resorption rim, but careful examination leads to the conclusion that the minerals are of separate origin, and their proximity due simply to mechanical segregation during the solidification of the rock.

In the noryte proper the orthorhombic pyroxene is the predominating ferro-magnesian constituent. It occurs here in well developed prismatic crystals with distinct cleavage parallel (100) (010) and (110) and strong pleochroism; parallel (a) purplish to reddish brown, parallel (b) light brownish yellow. parallel (c) pale green. It is, furthermore, easily recognized by the characteristic metallic luster (schillerization) produced by original inclusions of thin, rectangular plates of brown titanic

*See P. Becke., op. cit., p. 355.

iron ore, arranged parallel to the brachypinacoid (010), with their longer sides coinciding with the axis a of the hypersthene. These inclusions are identical in origin with those in the hypersthene of the Baltimore gabbros, as described by Williams* and cannot be considered as products of decomposition.† The hypersthene is not infrequently surrounded by a fringe of uralitic hornblende, which in many cases, replaces the entire crystal, and is optically hardly distinguishable from the actinolite resulting from the olivine.

A distinctive mineralogical feature of the Monhegan rocks is the subordinate position occupied by the monoclinic pyroxene. In the noritic types it is usually absent or distributed sporadically in the form of irregular grains heavily charged with magmatic inclusions. It is in the gabbroitic facies only that this mineral assumes larger proportions. The greenish brown, thick, tabular crystals are of irregular outline, and but slightly pleochroitic. They show well developed prismatic cleavage and the orthopinacoidal parting characteristic of diallage. On sections parallel to the plane of symmetry these crystals extinguish at an angle (c:**c**) of about 38° with the trace of the prismatic cleavage. The diallage is replete with ferritic inclusions, quite similar in character to those of the hypersthene, and is, in general considerably uralitized.

Magnetite and apatite are common in the Monhegan rock types—the former fluctuating quantitatively in direct proportion to the bi-silicates.

Apart from the fibrous aggregations of uralitic hornblende and actinolite already mentioned, the microscope reveals in nearly every instance small grains of a brown, primary hornblende. This mineral can best be described in the hornblende-gabbro which forms mineralogically a connecting link between the olivine-noryte and gabbro-dioryte. The rock is dark gray, almost black, and porphyritic in structure. Phenocrysts of bytownite and hornblende are embedded in a dense, coarse-grained ground mass composed of hornblende, diallage, hypersthene, bytownite, and magnetite in about equal proportions, and all, excepting the hornblende, pan-idiomorphically

*Bull. 28, U. S. G. S., 1886, pp. 23-24.

†See J. W. Judd: Teritary Peridotites of the Western Islands of Scotland, Q. J. Geol. Soc., Vol. 41, p. 383, August, 1885.

developed. This latter mineral (of both generations) is poikilitically intergrown with pyroxene, magnetite and feldspar crystals, which in thin sections gives it a very characteristic mottled appearance. The hornblende is of dark brown color and strongly pleochroitic: parallel **b** and **c**=chestnut brown, parallel **a**=yellow. Absorption is **c** > **b** > **a**

The poorly developed crystals vary in size from 1 mm-2 cm and have well defined prismatic cleavage, against which a maximum extinction (c:**c**) of 14° was determined. The above physical properties correspond almost exactly with those of a brown hornblende from the hornblende-gabbro near Pavone, Upper Italy, described by van Horn* and regarded by him to be syntagmatite† plus a normal-orthosilicate molecule (R_2SiO_4) with the constitutional formula: $(H, K, Na)_2$ $(Mg. Fe, Ca)_4$ $(Al, Fe)_2$ Si_4 O_{16}.

It will be remembered that in discussing the mineral components of the olivine-noryte, attention was called to the fact that in many cases olivine and feldspar were more or less completely replaced by secondary amphibole (tremolite and actinolite) accompanied by chlorite and sometimes biotite. This highly metamorphosed rock may be termed, altered, or amphibolized noryte in contrast to the amphibole bearing gabbro-dioryte, which is genetically more directly connected with the gabbroitic phase of the noryte proper, and can only be distinguished macroscopically from this rock by its dark green or grayish green color and variable coarseness of grain (see p. 332).

With the aid of the microscope the gabbro-dioryte is seen to be composed of basic feldspar, green hornblende, magnetite, biotite, apatite and frequently diallage more or less uralitized.

The alteration of diallage to green hornblende (uralite) by paramorphism has, thanks to Williams, Chester ‡ and others, been so well described that it needs no special mention here. It may, however, be of interest to note that many of the sections contained, besides this fibrous amphibole, another of massive structure and idiomorphic form. These crystals are

*Pet. Untersuchungen ueber die nortische Gestiene der Umgebung von Ivrea in Oberitalien. Min. u. pet. Mitth., XVII B., 5 Heft, 1897, pp. 19-23.

†See R. Scharizer, neues Jahrb., 1884, II, p. 142.

‡Bull. 59, U. S. G. S., pp. 25-27.

of prismatic habit and dark green color. Pleochroism is strong: parallel c and b=dark brownish green, parallel a=greenish yellow. Absorption (c > b > a), and an extinction angle (c:c) of about 18° are characteristic of dioritic hornblende.

With the increase of this primary amphibole the gabbroitic character of the rock changes until finally a rock is reached composed entirely of this mineral, associated with plagioclase, reddish brown mica, magnetite, apatite and some little quartz. This is the most acid rock of the area studied, and differs from a typical dioryte solely in the basic character of the plagioclase.

A specific gravity determination of this feldspar gave about the same result as that obtained for the bytownite (sp. gr. 2.681). With the aid of the microscope, however, it was found to consist of a larger interior portion, with the optical properties of bytownite and a narrow outer shell, perfectly free from inclusions, and having the small extinction angles of andesine (a:a =about 4° on (001) and 9° on (010).

A striking feature in the geology of Monhegan are the dike-like masses (segregation veins) already referred to (p.332) Intrusions of this kind are very common in gabbro areas generally and have been treated at length by various authors.*

On Monhegan two distinct types were readily recognized; one composed almost entirely of bytownite (labradorfelse)—being by far the most common in the region, and

*See G. H. Williams: Bull. 28, U. S. G. S., p. 25.
F. D. Adams: loc. cit., p. 449.
W. S. Bailey: The Basic Massive Rocks of the Lake Superior region. Jour. of Geol., Vol. III, pp. 815-24.
A. C. Lawson: Rept. on the Geology of the Rainy Lake Region, Geol. Survey of Canada, Ann. Rept., 1887, Vol. III, Appendix L, p. 73.
A. H. Elftman: Notes upon the Bedded and Banded Structures of the Gabbro, etc. Geol. & Nat. Hist. Survey of Minn., 23rd Rept., 1894, pp. 224-30, and Amer. Geol., 1898. Vol. XXII, pp. 135-43.
Alfred Harker: Carrock Fell: A study in the Variation of Igneous Rockmasses. Quart. Jour. Geol. Soc., London, 1894, p. 316.
J. W. Judd: op. cit., p. 49.
A Geikie and J. J. Teall: On the Banded structures of some Tertiary Gabbros in the Isle of Skye. Q. J. G. S., 1894, pp. 652-53.
C. Chelius: Lucitporphyrit, ein Ganggestein von Ernsthofen und seine Beziehungen zu den auderen Diorit und Gabbro Ganggesteinen des Odenwaldes. Notizbl. d. ver. f. Erdk. d. Grossh. geol. Landesanst. zu Darmstadt. IV. Folge 18. pp. 14-22.
C. F. Kolderup: Die Labradorfelse des westlichen Norwegens. Neues Jahrb., 1899, Vol. 1, p. 451.

the other made up of pyroxene with some little bytownite, magnetite and apatite (gabbro-pyroxenyte). Bands of extremely coarse grained noryte occupy mineralogically and geologically an intermediate position between the two. These dike-like masses have an irregular lenticular form without persistency in strike or dip. They can rarely be followed for more than 20-30 yards, and terminate generally in narrow veins and stringers while merging laterally into the surrounding rock without definite planes of contact.

The mineralogical interest of these rocks is confined chiefly to the pyroxenyte, which is of a dark gray color in contrast to the lighter purplish gray of the feldspar aggregates.

The pyroxene of the one dark vein critically examined is a brownish green augite resembling diopside. It is of crude prismatic habit and has well defined cleavage parallel (110). It is furthermore characterized by the unusual position of the optical constants; the axis of greater elasticity ($\mathfrak{a}$) being nearer the crystallographic axis c (parallel to the cleavage) than that of least elasticity; as is generally the case $\wedge$ $\mathfrak{a}:\mathfrak{c}$=about 38° in maximo. Dispersion of the bisectrices is recognizable: the angle $c:\mathfrak{a}_{\rho} < c:\mathfrak{a}_{v}$. Pleochroism is strong: parallel $\mathfrak{c}$ apple green, parallel $\mathfrak{b}$ greenish yellow, parallel $\mathfrak{a}$ purplish brown. Absorption: $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$.

A diopside-like pyroxene of almost identical physical properties, has been described by Broegger* from some of the coarse grained dikes near Frederiksvärn, Norway, but there the mineral appears to grade into aegirine, which is not the case in the Monhegan dike. Microlitic inclusions of opaque ilmenite needles, arranged crystallographically very much like those in the bytownite, are very plentiful in this pyroxene.

The chemical relationship of the rocks just described is shown by the following analyses:

I. Olivine-noryte.†

*W. C. Broegger: Min. der sudnorweg. Augitsyenite. Zeit. fur Kryst., 1890, Vol. 16, p. 656.

†In order to secure material representing as nearly as possible the average composition of the rock-types described under this heading. 6 specimens were selected that united yielded a mass composed (by volume) of approximately 60 per cent bytownite, 20 per cent olivine, 10 per cent hypersthene, 10 per cent actinolite+diallage+magnetite+apatite.

II. Hornblende-gabbro from near Seal Ledge.
III. Gabbro-dioryte from Green Point.*
IV. Labradofels from Burnt Head.
V. Gabbro-pyroxenyte from Burnt Head.
VI. Diopside from No. V.
VII. Green augite from the Cape Verde Islands.
(Praya San Thiago).†

	I	II	III	IV	V	VI	VII
SiO_2	40.61	44.79	47.2	45.78	43.17	42.55	43.99
TiO_2	.65	1.84	.84		1.56	1.66	
Al_2O_3	25.90	15.18	18.64	30.39	9.93	11.72	14.01
Fe_2O_3	2.18	4.13	1.96	1.33	8.78	3.75	2.09
FeO	5.37	8.21	6.82	1.22	6.88	6.74	8.84
MgO	7.69	7.93	8.28	2.14	6.80	8.88	10.88
CaO	14.50	14.10	11.52	16.66	20.96	22.51	19.42
Na_2O	2.31	2.18	2.91	1.66	1.77	1.55	1.09
K_2O	.25	.30	.28	.10	.16	.05	
Ign.	.78	1.33	1.44	.51	.31	.49	
	100.24	99.99	99.89	99.79	100.30	99.90	100.32
Spec. gr.	2.91	3.04	2.02	2.83	3.28	3.36	

The above analyses reveal the general character of the rock very clearly. Differences in the chemical composition of the various types are quite in keeping with their mineralogical fluctuations. Thus we find the hornblende-gabbro (II), rich in pyroxene (hypersthene and diallage) and brown hornblende, contains more iron (4.79 per cent) and SiO_2 (4.13), and less Al_2O_3 (10.72 per cent) than the olivine bearing feldspathic noryte (I). The high per cent of SiO_2 (47.2) in the gabbro-dioryte (III) combined with 18.64 per cent Al_2O_3 and but 11.52 CaO may be explained by the presence of some quartz and acid feldspar (andesine) in this rock. (See p. 338.)

The labradorfels (IV) and gabbro-pyroxenyte (V) representing the products of extreme differentiation of the noritic magma, show the most pronounced chemical differences. Thus No. IV, composed almost entirely of bytownite (see An. p.333) has considerable more SiO_2, Al_2O_3, CaO and over 10 per cent

*No. III is a mass analysis of six specimens of gabbro-dioryte containing approximately 45 per cent actinolite (uralite) 20 per cent bytownite. 5 per cent andesine. 20 per cent primary green hornblende, 10 per cent magnetite+apatite+quartz+mica.

†See Hinze: Handb. der Min., p. 1112 (CCCVIII).

less iron and magnesia than the olivine-noryte (I); while No. V, being chiefly pure diopside. VI contains over 7 per cent more iron and magnesia and nearly 16 per cent less Al_2O_3 than the same rock. It is of interest, further, to note that both of the derived rock-types are appreciably more acid than the noryte magma (I).

The composition of the diopside (VI) from the gabbro-pyroxenyte (V) presents some interesting features which may be discussed somewhat more critically. For comparison the analysis of a grass green augite from the augite-phonolyte of the Cape Verde islands is given (VII).* Both these minerals contain an unusually high per cent of $CaO+Al_2O_3$ (34.26 and 33.45) combined with but 42.55 and 43.99 SiO_2; leaving only about 22% for the remaining elements. These facts indicate the presence of an alumosilicate ($H_2Al_2SiO_6$)* in the constitution of the pyroxene, and enables the analysis to be interpreted as follows:

SiO_2	26.62%		
FeO	6.74		
MgO	5.12		
CaO	12.50		
	50.99	$Ca(Mg, Fe)Si_2O_6$	
SiO_2	6.78		
Al_2O_3	11.52		
MgO	.83		
CaO	5.15		
	24.28	$(Ca, Mg)Al_2SiO_6$	
SiO_2	4.39		
CaO	4.09		98.27 Pyroxene
MgO	2.93		
	11.41	$CaMgSiO_3$	
SiO_2	5.60		
Fe_2O_3	3.75		
Na_2O	1.46		
	10.81	$Na_2Fe_2Si_4O_{12}$	
SiO_2	.47		
Al_2O_3	.20		
Na_2O	.12		
	.79	$Na_2Al_2Si_4O_{12}$	

*See Naumann-Zirkel: Elemente der Min., 1898, p. 686.

Residue: .83% CaO+.49% ignition+.41% (1.66 TiO_2 less equivalent SiO_2)=1.73%.

Acid and Basic Dikes of the Region.

As has already been stated (p.332) fissure instrusions are of common occurrence in the Monhegan mass. They are indeed so numerous that it was not attempted to represent all on the map. These dikes belong to two great systems of intrusions, differing in time of eruption, as well as in mineral composition. To one system belong all the basic dikes closely allied geologically and mineralogically with the basic rock of the region; and to the other the granitic and aplitic types belonging to a later period of eruption and in no way connected genetically with the Monhegan mass. It is of interest to note that the basic dikes are confined almost exclusively to the island, and have little or no uniformity in strike; whereas those of granitic character, with but one or two exceptions, extend uninterruptedly in a N. 50°-60°W. direction across the island, and could be identified again on the main land some twelve miles distant. These acid dikes vary in width from 6 inches to as many feet, and in texture from a fine grained soda-aplyte composed of albite, muscovite, quartz and accessory garnet, cordierite and magnetite, to a coarse granular pegmatitic granite made up principally of albite > quartz > muscovite > orthoclase > garneta > apatite > magnetite.

The exceptions referred to are of two dikes from 6 in. to a foot in thickness outcropping along the eastern face of Burnt Head, and continuing in a northerly direction to White Head; a distance of about ½ mile. The rock is characterized by the presence of biotite and blue and black tourmaline graphically intergrown with quartz.

The texture of these dikes is usually quite uniform, but in some instances rocks of granitic and aplitic character occur within the same vein. Here the aplyte occupies the central part of the dike mass in such a manner as to suggest a later intrusion. The results of a chemical analysis of this aplyte (No. 17) is given under I, and under II that of a similar rock

(soda-ganulyte) from near Mariposa, California,* is reproduced for comparison.

		II
SiO_2	74.78	74.21
TiO_2		.30
Al_2O_3	14.56	14.47
Fe_2O_3	3.04	.35
FeO		.50
CaO	.69	1.71
MgO	trace	.28
Na_2O	6.02	7.62
K_2O	.59	.10
Ign	.42	.38
P_2O_5		.07
Total	100.10	99.99
Spec. gr.	2.64	

The rather large amount of iron in I may be attributed to the presence of garnet and cordierite; the latter mineral being frequently altered to a fibrous mass (pinite?) strongly impregnated with limonite.

In other respects both analyses are essentially identical.

The abnormally high percentage of soda and silica combined with but .69% CaO clearly indicates an acid member of the albite group (Ab_{12}:An_1) as the principal constituent of the rock.

The basic dikes of the area are of special interest as they may be taken to represent products of deep seated differentiation peculiar to the noryte magma. Dikes of quite similar character are by no means rare and have received careful treatment by various authors.†

*See H. W. Turner: 17th Ann. Rept., U. S. G. S., Part I, p. 721.

†See F. D. Adams: op. cit., p. 434, Rept. on the Geology of the Laurentian Area of Montreal. Ann. Rept., Geol. Soc. Canada, Vol. VIII, 1895, pp. 134-139.

G. H. Williams: The Gabbros and Diorites of the "Cortlandt Series." op. cit., p. 442.

J. F. Kemp: Gabbros on the Western Shore of Lake Champlain op. cit., p. 223. and A Diorite Dike at Forest of Dean, Orange Co., N. Y., Amer. Jour. Sci., XXXV, 1888, p. 331.

W. D. Matthews: op. cit., p. 197.

W. S. Bayley: The Eruptive and Sedimentary Rocks of Pigeon Pt., Minn., U. S. G. S., Bull., 109, 1893, p. 44.

A glance at the map will make clear the irregular distribution of these dikes. They are all of contemporaneous origin, occupying probably original fissures in the Monhegan mass which are in no wise connected with subsequent zones of fracture. The dikes are themselves sheared and faulted to as great a degree as the rock in which they are intruded, and they are intersected by the granite dikes, already mentioned, which are consequently of more recent age.

These dikes vary in thickness from a few inches to not more than three feet. They have but little persistency in strike, and only in rare instances could be traced for a considerable distance from the shore. The rock varies in color from dark steel gray to brownish or purplish gray, and in texture from aphanitic to medium granular. The structure is panidiomorphic granular throughout; in contrast to that of the porphyritic diabase and camptonyte dikes, on the main-land.*

The rock is remarkably fresh and exhibits none of the pronounced effects of erosion characteristic of the camptonytes. While showing, macroscopically, unappreciable differences, under the microscope, the mineral composition of these dikes is seen to lie between that of a hypersthene-gabbro on the one hand and gabbro-dioryte on the other—both extremes being connected by types resembling hornblende-gabbro. Adopting the classification of Chelius and Osann, the

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A. C. Lawson: op. cit., pp. 154-157, (F). and Amer. Geol., VII. 1891, p. 153.

U. S. Grant: The Geology of the Gabbro Lake Plate, Geol. and Nat. Hist. Survey of Minn., Vol. 4, 1896-98, p. 409.

H. B. Patton: op. cit., p. 185.

A. H. Elftman: loc. cit.

H. W. Fairbanks: The Geol. of Point Sal, Cal., Bull. Dept. Geol., Univ. of Cal., Vol. II, No. 1, 1896, pp. 50-74.

C. Chelius: Das Granitmassiv des Melibocus und seine Ganggesteine. Notiz. d. Ver. fur Erdk., Darmstadt, 1892, IV. Folge, 13 Heft, pp. 1-13, and 1894, IV Folge, 15 Heft, pp. 16-33.

A. Osann: Ueber die dioritische Ganggesteine im Odenwald. Mitth. d. Gross. Bad. Geol. Landesanstalt, 1892, II, p. 380.

C. F. Kolderup: op. cit., p. 451.

J. A. L. Henderson: Pet. and Geol. Investigations on certain Transvaal Norites etc., London, 1898. (Dulau & Co., 37 Soho Sq.) p. 51.

T. H. Holland: Basic Dikes in Norite from Southern India. Neues. Jahrb., Bd. II, Heft 3, 1898, pp. 441-83; and on Augite-Diorites with Micropegmatite. Q. J. G. Soc., 1897, pp. 403-417.

*See E. C. E. Lord: On the Dikes in the Vicinity of Portland, Me. Am. Geol., Vol. XXII, Dec., 1898, p. 339.

gabbroitic intrusions have been termed beerbachyte (aplitic gabbro), and the dioritic, malchyte, (aplitic dioryte).

It is of interest to note that olivine, the prevailing ferromagnesian constituent of the olivine-noryte, is lacking in the dike rocks, and, further, that feldspar no longer preponderates over other ingredients.

Beerbachyte (5, 6, 10, 16) consists of an even granular mass of diopside, hypersthene and bytownite, in about equal proportions, associated with magnetite and a few scattering grains of apatite. These ingredients differ only structurally from those described in connection with the olivine-noryte. In many of the specimens (1, 2, 3, 13, 14, 24, 26, 27) brown hornblende, identical with that of the hornblende gabbro, enters into the composition of the rock; sometimes to the almost complete exclusion of the pyroxene (2, 24, 26). This brown hornblende and more especially the pyroxene, is, furthermore, frequently replaced by green hornblende, as a result of uralitization, which is not readily distinguished from the primary amphibole of the malchyte. (See below)

A peculiar feature of the beerbachyte as well as of other rocks of the region is the frequent occurrence of veins and seams of secondary green hornblende. These were at first supposed to be magmatic segregations, but on close inspection they were found to follow continuously the joint and rift planes in the rock, which would indicate that uralitic hornblende is not necessarily of prescribed local development, but may, under favorable conditions, occur along independent zones of fracture metamorphic agencies have been most active.

Chlorite and limonite are the principal products of atmospheric weathering of these rocks.

Malchyte (4, 7, 9, 11, 20, 21, 23, 25, 28, 29) is dark steel gray in color, and of even granular structure, very similar to beerbachyte. The rock is composed essentially of dark green hornblende and bytownite, with accessory biotite, magnetite (pyrite) and apatite. The hornblende is of short prismatic form, with the large angle of extinction (angle c: $\mathfrak{c}$=about 18°), pleochroism (parallel $\mathfrak{c}$=green, parallel $\mathfrak{b}$= brownish green, parallel $\mathfrak{a}$=greenish yellow) and absorption ($\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$) characterizing the primary hornblende of the gabbrodioryte. (p. 338).

Products of weathering and metamorphism are similar to those of the beerbachyte.

No distinct line of demarcation could be drawn between these two rock-types. Beerbachyte grades into malchyte through an increase in green hornblende with a proportional decrease of the pyroxenes in the same manner that hornblende-gabbro merges into gabbro-dioryte. The parallelism in the mineral composition of the dike rocks with their deep-seated prototypes is further emphasized by the fact that some specimens of malchyte (22, 23) contains quartz, andesine and biotite, as is the case in the more acid varieties of gabbro-dioryte (see p. 338). These specimens may be referable to the luciite of Chelius,* although no analysis has been made of them.

The chemical relation of these basic dikes with the gabbroitic facies of the noritic magma is brought out by the following analyses.

The average chemical composition of beerbachyte is given under I and that of malchyte under II.† For comparison the analysis of hornblende-gabbro (III) and gabbro-dioryte (IV) have been reproduced, and the average composition of III-IV and I-II given under V and VI respectively.

	I	II	III	IV	V	VI
SiO_2	46.29	45.66	44.79	47.20	45.99	45.97
TiO_2	1.21	1.39	1.84	.84	1.34	1.30
Al_2O_3	17.16	16.26	15.18	18.64	16.91	16.71
Fe_2O_3	2.57	2.97	4.13	1.96	3.04	2.77
FeO	9.87	8.51	8.21	6.82	7.51	9.17
MgO	7.79	10.21	7.93	8.28	8.13	9.00
CaO	12.04	12.25	14.10	11.52	12.81	12.14
Na_2O	2.21	1.34	2.18	2.91	2.54	1.77
K_2O	.16	.31	.30	.28	.29	.13
Ign	.51	.92	1.33	1.44	1.38	.74
Total	99.81	99.82	99.99	99.89	99.94	99.81
Spec. gr.	3.06	3.04	3.04	3.02	3.05	3.03

It will be noticed at a glance at the above tables that, excepting slight differences in the proportions of FeO and MgO,

* Notizbl. des Ver f. Erdkh., 1894, IV Folge, p. 32.

†The material for these analyses was obtained by uniting an equal amount (by volume) of rock powder from six specimens of beerbachyte (3, 5, 6, 10, 14, 16) and five of malchyte (4, 7, 23, 20, 21)).

beerbachyte (I) and malchyte (II) have essentially the same composition. The mean of these two analyses (VI) is seen, to correspond almost exactly with that of gabbro-dioryte and hornblende-gabbro (V)—the only appreciable difference being in MgO, FeO, which is 2.53% larger in the dike rocks (VI) than in the gabbro and gabbrodioryte (V).

From this striking chemical as well as mineralogical analogy it is apparent that these dikes represent but another form of the same gabbroitic magma which, fluctuating within the limits of columns III and IV, has itself reached an advanced stage of differentiation from that of the common magma. (See Analysis I p. 340.)

It is also probable judging by the intimate geological as well as mineralogical relations of the main rock types that this differentiation was caused by slight local changes in the physical and chemical conditions during the solidification of the liquid mass after it had reached essentially its present geological position. The presence of numerous dikes, exhibiting the same mineralogical variations as occurred in the main rock mass itself, substantiates this view, and points, furthermore, to the very gradual and uniform character of the magmatic fluctuations.

Monhegan has participated in the principal orographic and epirogenetic movements of the adjoining province, and may well be considered a part of it(see p.329),although rocks of similar description were not found on the neighboring islands, nor in the immediate vicinity on the mainland.

Owing to the isolated position of the island and the absence of sedimentary rocks upon it, but little more can be said of its geologic age than that the intrusion antedated that of the granitic dikes.

Very similar conditions are found on the island of Vinal Haven* where the diabasic gabbro, (black granite), of post-Niagara age is intersected by younger granitic intrusions. If this diabase is indeed a geological equivalent of the Monhegan rock, which on purely petrographic grounds seeems probable, both intrusions would be of late Devonian age.

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*See G. O. Smith, op. cit., p. 64-65.

MINERALOGICAL AND PETROGRAPHIC STUDY OF THE GABBROID ROCKS OF MINNESOTA, AND MORE PARTICULARLY, OF THE PLAGIOCLASYTES.

[Continued. See plates in the September and October Numbers.]

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CHAPTER VIII. Quartz Gabbro.

The type of this abnormal rock came from the S. E. ¼ S. W. ¼ Sec. 12, T. 64-6, near Little Saganaga lake, a locality situated at the northern edge of the gabbro area.

The rock is medium to coarse grained, granular to porphyritic in texture, with occasional irregular parallelisms in the arrangement of the dark minerals. It is often decomposed, and then can be crumbled rather easily.

The rock is of a mottled greenish-gray color, usually rather light in shade. In the porphyritic varieties the phenocrysts of plagioclase with their polysynthetic twinning are usually greenish, but occasionally they seem to be reddish, though no twinning is then visible, probably on account of decomposition. Glassy quartz is not very abundant while apatite scales are rare. The common dark green mineral resembles a pyroxene, but is evidently decomposed. On weathering the feldspar first disappears, leaving quartz and biotite conspicuous. The color remains practically unchanged.

TEXTURE. Under the microscope the decomposition of the rock is very noticeable. The feldspar is very often altered to a sericitic mass; the pyroxene is entirely transformed to penninite with a little biotite. But the texture is still quite distinct; it is coarsely granitic with the usual order of crystallization, namely, zircon, apatite, pyroxene(?), plagioclase, quartz. Magnetite is very rare, or perhaps wanting, as a primary mineral. Olivine was also doubtless present, though uncommon in the fresh rock; it is now represented only by nearly amorphous masses of bowlingite, which, however, still retain the form of the original, irregularly developed olivine. The latter certainly solidified before the plagioclase, and apparently before the pyroxene.

PRIMARY MINERALS. *Quartz* occurs in large irreg-

lar masses surrounding or cementing the elements. Occasionally the andesine penetrates the quartz.

The liquid and gaseous inclusions are usually irregularly distributed. Movable bubbles have been noted.

Secondary quartz is not uncommon. It usually produces "quartz enlargements" by orienting itself exactly on the nearest primary quartz. (See plate XII, figure 2.) It also occurs in minute veins, and small masses of arbitrary orientation.

Andesine is the only feldspar which has been found. It occurs in the usual large xenomorphic forms with the albite twinning nearly universal, and the pericline and Carlsbad twinning occasionally added.

In mass the andesine is green or red from numberless alteration products; in section it is usually very cloudy from the same cause. The mineral seems to be positive with a very large optic angle. The maximum extinction in the zone perpendicular to $g^1(010)$ exceeds 20°; extinction in Sn_g does not seem to exceed 5°; perpendicular to n_p it is about 65°; cleavage pieces parallel to $p(001)$ give an extinction of about 2°; parallel to $g^1(010)$, it is about 10°. The composition of the plagioclase is therefore very near $Ab_3\ An_2$.

The alteration products of the feldspar are calcite and a sericitic mineral; more rarely epidote, penninite, quartz, and hematite appear within the andesine.

Apatite is usually well formed and always automorphic. It is sparsely distributed, but occurs in rather large acicular crystals terminated by the basal plane or a steep pyramid, or both. The faces definitely identified are: $p(0001)$, $m(10\bar{1}0)$, $b^1(10\bar{1}1)$, and $h^1(11\bar{2}0)$.

Liquid and gaseous inclusions are sometimes abundant, and are usually arranged along planes, either crystallographic or curving.

Zircon occurs in very small, well formed, rectangular crystals, which are practically colorless in thin section. The mineral is rather rare, and perhaps would be overlooked if it did not cause intense halos in the penninite and biotite, where it is generally found. In these halos the birefringence of the chlorite is increased about .002; and the refringence is increased also. (See plate XIX, figure 20.)

SECONDARY MINERALS. *Biotite* is not abundant. It

is probably all secondary in origin, and is in turn altering to penninite. It occurs in thin lamellæ with perfect basal cleavage. It is sometimes bent, or even broken. Green biotite occurs rarely. The pleochroism is very strong.

n_g =	dark seal brown	green
n_m =	seal brown	green
n_p =	pale brownish yellow or clear yellow	pale green

The alteration to penninite is a very gradual degeneration usually affecting, either all of one mass, or all of certain lamellæ, at once. The change is first to green biotite with undiminished birefringence. Very gradually the color fades and at the same time the birefringence and the pleochroism diminish till finally penninite results. Biotite shows pleochroic halos about zircon, apatite, and rutile needles.

Penninite is the common ferromagnesian element of the rock. It was probably derived in part directly from the primary pyroxene, whose existence is clearly indicated by the magnetite, which, in separating out, has preserved the trace of the original prismatic cleavages at about 93° This is well shown in plate XIX, figure 21. The chlorite is clearly derived also from biotite, and very possibly in part also from an amphibole, in turn derived from a pyroxene. The habit of the penninite is lamellar with micaceous cleavage. Twinning parallel to the base $p(001)$ occurs. The color and pleochroism are slightly variable in intensity, always in green shades with:

	Penninite +	Penninite —
n_g =	very pale yellowish green to colorless	green
n_m =	green	green
n_p =	green	very pale yellowishgreen to colorless

The absorption is:

Penninite +	$n_g < n_m = n_p$
Penninite -	$n_g = n_m > n_p$

Thus the maximum absorption is always parallel with the cleavage and elongation, since the bisectrix is always perpendicular to the basal plane.

The birefringence is extremely weak, and the interference colors are "ultra blue" (and pale yellowish) on account of the strong dispersion.

Penninite in thin section is sensibly uniaxial, usually negative; but also sometimes positive. Both varieties occur in this rock. The elongation of the common negative penninite is positive with extinction sensibly parallel.

Inclusions are abundant. They consist of magnetite, apatite, zircon and rutile. About all except magnetite are halos, faint about the rutile needles, even when a mass of needles multiplies the effect. (See plate XIX, figure 22.)

About the apatite the halos are stronger than about rutile, but markedly less intense than those about zircon. In all these cases the birefringence is increased sensibly; but in the case of rutile the increase is so slight as to escape an approximate evaluation; about apatite the increase is about .001, while about zircon it is at least .002. It can therefore be concluded that in a given mineral the increase in the birefringence in pleochroic halos is proportional to the intensity of the latter. The increase in the refringnce cannot be accurately determined, but it apparently follows the same law.

Rutile occurs both in the form of acicular crystals noted above, and in small shapeless masses from which needles often radiate. The needles are strongly striated parallel to the vertical axis. They present characteristic twinning both "en genou" and "en coeur." Rutile is brown with weak pleochroism:

n_g =light violet brown.
n_p =yellowish brown.

In reflected light the masses of needles give a dull light green color. The extreme refringence gives a very high relief.

Rutile is abundant in the penninite (See plate XII, figure 2), and shows that one or both of the minerals [pyroxene and magnetite*] from which the chlorite has been derived were quite rich in titanic acid. It is rarely found elsewhere in the rock.

Magnetite perhaps occurred in small quantity as an original constituent of the rock. But the mineral is not rare as an alteration product, being especially produced by the alteration

*Penninite is derived from magnetite by mesogenesis between the latter and plagioclase. But more commonly biotite forms first by mesogenesis, and in turn alters to penninite.

of the original pyroxene, whose cleavage lines have thus been preserved occasionally (See plate XII, figure 21).

Calcite is abundant in the andesine and even in the pennin-ite. It is in irregular masses showing twinning and cleavage parallel to the rhombhedral faces.

Bowlingite preserves the irregular form of the primary olivine. (See plate XIX, figure 23.) It is now nearly amorphous, and only feebly birefringent. The pleochroism is not sensible, but the color in various parts varies from brownish yellow to yellowish green. The refringence (N) seems to be practically equal to n_g of calcite.

Epidote occurs rarely in irregularly automorphic, small crystals.

A sericitic mineral is abundant as a decomposition product of the andesine, and the chemical composition of the rock renders it possible that it is paragonite rather than muscovite. The mineral is fibrous or lamellar in habit with a refringence higher than that of andesine, and birefringence at least .031 (n_g —n_p.) The elongation is positive, with extinction sensibly parallel.

THE CHIEF FEATURE OF THE CHEMICAL COMPOSITION is naturally the high per cent of silica; the amount of titanium is very noticeable; it was evidently originally in the pyroxene and magnetite (?), and is now in the form of rutile.

	I.
SiO_2	56.60
TiO_2	1.59
Al_2O_3	17.84
Fe_2O_3	2.55
FeO	4.09
MnO	Trace
MgO	3.16
CaO	6.28
Na_2O	4.45
K_2O	.45
H_2O	3.20
P_2O_5	.14
	100.35
Sp. Gr.	2.36
	-2.41

I. Quartz gabbro (854G) from near Little Saganaga lake. No appreciable BaO nor SrO; Fl and CO_2 not determined.

The ORIGIN of this rock is not as clear as that of the preceding, but the presence of a large amount of quartz indicates that it is the result of the absorption by the normal gabbro of clastic siliceous rocks. It is derived, indeed, from the northern extremity of the area of gabbros where the latter were in contact with various older rocks; the quartz gabbro is associated with the noryte.

CHAPTER IX. Silicoferrolyte.

The name ferrolyte was first proposed by Wadsworth* in 1892 to designate a rock essentially composed of iron ores.

In this chapter will be studied a rock extremely rich in magnetite, and it is proposed to employ the term silicoferrolyte to designate it.

It contains, in fact, a remarkable quantity of quartz, and of a ferruginous silicate, and it seems preferable to leave to the term proposed by Wadsworth its more general signification. Silicoferrolyte is the rock designated "olivine iron ore" by the Minnesota Geological Survey. It is, indeed, composed essentially of magnetite, fayalite and a small quantity of pyroxene; these three minerals enclose numerous small grains of quartz. The magnetite is in such quantity as nearly to constitute a paying iron ore. But in the state which leads the world in the production of iron of very high grade, low grade ores naturally pass unnoticed.

The sample to be studied came from the north side of Birch lake, near the northern edge of the gabbro area. According to N. H. Winchell silicoferrolytes pass into gabbros by insensible gradations. Occurrences of a similar rock are known farther east along the northern border of the gabbro, and others occur near Duluth, and at points well within the gabbro area.

Silicoferrolyte often presents a rough schistosity which may sometimes be seen even in hand specimens. The color of the rock is that of the dominant mineral, namely, black, with bright metallic lustre on fresh surfaces. Occasionally the rock is greenish black, when the fayalite is abundant. Magnetite and fayalite are the only minerals distinguishable

*M. E. Wadsworth: Rept. State Geol. Mich. 1891-92. p. 92. Ref. Kemp: Handbook of Rocks. 1896. p. 137.

without the microscope. On decomposition the rock first becomes rusty, as hematite is formed on the surface; then it becomes dark greenish as the fayalite alters to bowlingite, etc.

TEXTURE. Under the microscope the silicoferrolyte is found to have a marked poikilitic texture, large crystals of fayalite enclosing many magnetite grains, which very rarely show any crystal outline. Between the fayalite masses occur anhedra of pyroxene, only rarely surrounding the former because only rarely abundant enough. They may enclose, or be enclosed by, the fayalite. But the feature of the rock is the presence of many rounded grains of quartz scattered everywhere in the rock. These quartz grains are usually very small; they often present concavities, perhaps of the nature of embayments. They occur in multitude enclosed within the other minerals. (See plate XI, figure 1.) The orientation of these grains is wholly heterogeneous and this reenforces the poikilitic texture. The order of crystallization is:

Quartz.
Magnetite. Hercynite.
Fayalite.
Pyroxene.

No feldspar is found in the rock. The secondary minerals are neither numerous nor abundant, they include: actinolite, tremolite, bowlingite, göthite, hematite and the chlorites.

CONSTITUENT MINERALS. *Quartz* is such an unusual element of an ultrabasic rock that the diagnostics depended upon for its determination will be specified with care. It presents no crystal outlines, being always round or irregular. It shows no cleavage and no twinning. Undulatory extinction is very rare. The mineral is of a glassy transparency and perfectly colorless. The refringence is low, and n_p is inferior to the refringence of Canada balsam, but n_g is superior to the latter. The birefringence is .009. Sections directly perpendicular to n_g show that the mineral is strictly uniaxial and positive.

Liquid inclusions occasionally containing moving gaseous bubbles are not rare; they occur either irregularly, or along curving planes.

Magnetite is the most abundant component of the rock. It very rarely shows crystal outline; the octahedral parting,

however, is common. The composition of the rock shows that the magnetite is non-titaniferous.

Hercynite can not be distinguished in exterior or microscopic characters from magnetite. Its presence was first suspected from the fact that an excess of alumina exists in the rock. Its presence was established as follows: the coarse powder of the rock was digested in hot hydrochloric acid, changed now and then, and a little iodide of potassium added each time. This was continued until the attack by the acid had ceased. After filtering and drying, the quartz was eliminated by means of a heavy liquid, and an examination with the microscope showed that the residue was composed of augite and a spinel, resembling magnetite in outward characters. The augite was next eliminated by a rapid treatment with hydrofluoric acid, and the spinel, thus purified, was tested for magnesia, which was found only in traces. It must, therefore, be hercynite; it is in small amount in the rock, but evidently absorbs the excess of alumina.

Fayalite has heavier, but more irregular, cleavages than chrysolite. Cleavage parallel to $g^1(010)$ is especially good; more irregular cleavages parallel to $p(001)$ and $h^1(100)$ are common. Crystal outline does not occur. Fayalite is transparent and colorless in thin section; in mass it is greenish yellow, but readily colored darker green or brown by decomposition. The refringence is inferior to that of augite and superior to that of tremolite. The birefringence is stronger than that of chrysolite, with:

$$n_g - n_m = .009 \text{ at least.}$$
$$n_m - n_p = .029 \text{ at least.}$$
$$n_g - n_p = .038 \text{ at least.}$$

Fayalite is negative with an optic angle considerably smaller than in chrysolite. The dispersion about the acute bisectrix n_p is $\rho > v$. The chemical composition of the rock shows that the fayalite is non-manganiferous.

The *pyroxene* of the silicoferrolyte shows the usual prismatic cleavages very distinctly. Parting and fine twnning parallel to $h^1(100)$ also occur. Its birefringence is:

$$n_g - n_m = .016 \text{ at least.}$$
$$n_m - n_p = .007 \text{ at least.}$$
$$n_g - n_p = .023 \text{ at least.}$$

Tremolite occurs in the fibrous form, partially surrounded by fayalite.

Its birefringence is at least .024. The elongation of the fibers is always positive, with a maximum extinction angle of about 16°

Actinolite is simply a ferriferous tremolite, and differs from the latter only in its pale green color, distinct pleochroism, and slightly smaller maximum extinction angle. It seems to be derived from the tremolite by the addition of iron, and is undoubtedly always secondary. Its pleochroic colors are:

n_g = clear green
n_m = greenish ? yellow
n_p = pale yellow

The maximum extinction angle parallel to the elongation does not exceed 13°.

Bowlingite is the ordinary decomposition product of the fayalite. It occurs very sparingly, and is usually of lamellar habit. The color is quite variable, reddish-yellow, brown, or green. The pleochroism is remarkably weak.

Göthite is another more uncommon alteration product of fayalite, and can be distinguished from the reddish yellow bowlingite only by the fact that it has a higher refringence than the fayalite, while bowlingite has a lower. It has a red color, and a birefringence superior to .012. The lamellæ, apparently homogeneous, are found to be composed of many parts of varying orientation; this fact, together with a very strong dispersion, prevents extinction in white light.

Hematite occurs merely as a superficial rusty stain; it has not been found in sections of the rock. It is doubtless formed by oxidation of the magnetite.

Penninite and *clinochlore* have only been observed along fractures in the rock.

The CHEMICAL COMPOSITION of the silicoferrolyte is characterized by the high per cent of iron and extremely low silica. Titanium occurs in very small amount. This is the more surprising since the gabbros are so commonly titaniferous in this region. The very low per cent of alkalies is another notable feature. The per cent of water is surprisingly high.

In the following table is given for comparison a series of analyses of rocks, more or less similar, all derived from gabbro areas:

	I	II	III	IV	V	VI	VII
SiO_2	21.50	4.08	22.87	21.25	24.74	16.17	14.95
TiO_2....	trace	14.25	9.99	6.30	9.53	7.14	8.50
Al_2O_3....	8.02	6.40	10.64	5.55	6.99	5.34	8.95
Fe_2O_3...	30.54	33.43	Fe_3O_4	Fe_3O_4	24.58	35.20 }	52.85
FeO.....	33.53	34.58	44.88	43.45	21.86	23.22 }	
MnO....	.32	.45	2.05	.40	.69	.46	.30
MgO....	1.95	3.89	5.67	18.30	9.23	7.56	10.25
CaO.....	1.55	.65	.65	1.65	2.88	1.84	1.80
Na_2O....	.42	.29					
K_2O.....	.10	.15					
H_2O.....	2.77	1.32	3.05	2.60		.40	1.40
	100.70	99.71	100.00	99.66	100.61	98.42	99.14
Sp. Gr.	4.00 –4.04						

I. Silicoferrolyte (960) from Birch lake, Minn. No appreciable traces of BaO, nor SrO, nor Li_2O.

II. "Magnetite-Spinellite," from Routivara, by W. Petersson: Geol. För. Förh. B. 15. p. 49. 1893. With .20 Cr_2O_3 and .016 P_2O_5. Ref. W. C. Brögger: Das Ganggefolge des Laurdalits. 1898. p. 321.

III. Magnetite-olivinyte from Iron Mine Hill, Cumberland, R. I., described by M. E. Wadsworth; analysis quoted by Vogt: Bildung von Erzlagerstatten durch Differentiationsprocesse in basischen Eruptivmagmata. Zeit. f. prak. Geol. I. 1893. Includes also .20 Cu and traces of S and P_2O_5.

IV. Magnetite-olivinyte from Taberg, Sweden, described by Törnebohm: Geol. Fören. Förhand. B. 3, 1876; B. 5, 1881; B. 6, 1882. Analysis quoted by Vogt. Ibid. Includes also .127 P_2O_5, .013 S, .02 Cu, and trace of V_2O_5.

V. Titaniferous iron ore in olivine diabase,etc. from Ulfo; analysis quoted by Vogt Ibid. Includes also .07 P_2O_5, .03 Cu, and .01 S.

VI. Magnetite-olivinyte from Inglamåla, Sweden; analysis quoted by Vogt. Ibid. Includes also 1.02 S, .40 V_2O_5, .07 P_2O_5, and trace of Cu.

VII. Magnetite-olivinyte from Långhult, Sweden; analysis quoted by Vogt. Ibid. Includes also .118 P_2O_5, and .019 S.

The Minnesota type is entirely exceptional in its very low per cent of titanium. The small amount of magnesia and of calcium will be remarked at once; further, as in nearly all similar rocks* there is an excess of alumina which ex-

*The exceptions are very rare: See Vogt: Zeit. f. prak. Geol. I. 1873, and Kemp, who has recently studied the composition of these rocks in an article entitled: Titaniferous Iron Ores of the Adirondacks, 19th Ann. Rep. U. S. Geol. Survey, part III, p. 377. 1899.

presses itself in the mineralogical composition by the presence of hercynite.

ORIGIN. Several modes of formation suggest themselves for a rock of this character.

The hypothesis of its origin by means of a differentiation in the magma which gave birth to the gabbros and plagioclasytes must apparently be rejected, since the silicoferrolytes and the plagioclasytes can not be regarded as the opposite poles of a similar series. It will be noted in this connection that there does not exist in the silicoferrolyte the abundance of calcium, of magnesia, and of titanium which ought to be found if this hypothesis were correct, and which exists in nearly all the analogous rocks whose analyses are cited above. and whose origin has been explained by the aid of this hypothesis by the authors who have studied them. Furthermore, the existence of quartz would be very difficult to explain if one accepted this hypothesis.

The same reasons render improbable the hypothesis according to which the silicoferrolyte would be the result of an intimate mixture of a gabbro and of a quartzose sedimentary rock, a quartzyte, for example. Indeed, an examination of the chemical composition of the normal gabbro and of the silicoferrolyte (after deduction of about 10 per cent of quartz) shows that no rock mixed with the gabbro in equal parts could give birth to the silicoferrolyte; and even if one admit that one part of the gabbro could digest three parts of a foreign rock, the latter would have to have had the following composition: iron oxides, 90%, alumina 6.5%, and water 3.5%, and even then the resultant rock would contain no free quartz, which microscopic study shows to be quite abundant in the silicoferrolyte.

Furthermore, the existence of numerous grains of quartz enclosed by the fayalite, and by the magnetite seems an insurmountable argument against the hypothesis of the formation of this rock by pure igneous fusion. Indeed, it is difficult to understand how free quartz could have remained intact in a molten magma whose consolidation would have given birth to an orthosilicate of iron and to a very large amount of magnetite.

There remains, therefore, only one hypothesis which con-

sists in supposing that the silicoferrolyte is the result of exomorphic action of the gabbro upon a sedimentary rock originally composed of an impure iron ore, both quartzose and argilaceous. Its transformation has been effected not by means of pure igneous fusion, but by aqueo-igneous methods acting at a high temperature. In support of this hypothesis may be mentioned the fréquence of the production of fayalite associated with free silica under the influence of pneumatolitic agents in cavities in certain granites of Iceland,* and the great frequence of the same minerals in the lithophysæ of the rhyolytes of the Yellowstone Park,† of Lipari,‡ of Glade creek, Wyoming,§ and in those of the andesytes of Santorin,‖ etc.

CHAPTER X. Résumé and Conclusions.

COMPARATIVE PETROGRAPHY. The rocks studied in this article (except certain aberrant types) belong to a single petrographic family—that of the gabbros.

The rock considered to represent the normal, central type of this family is the olivine gabbro, which is a dark gray, granular aggregate of labradorite, pyroxene, and olivine, with more or less magnetite, and generally a few small crystals of apatite. It is nearly always in a remarkably fresh, unaltered condition. Its general structure is grandly massive with only occasionally a rude columnar arrangement on a very large scale; any approach to a bedded structure is very rare in the normal gabbro. Under the microscope the texture is found to be very coarsely granitoid with a tendency not uncommon to pass into a coarse ophitic texture.

The variations which this rock undergoes are of three distinct types:

1. Variations due to conditions of solidification.
2. Variations due to segregation, or original heterogeneity of the magma.

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*Delesse: Bull. Soc. Géol. France. II. X. p. 571.
†Iddings: 7th Ann. Rep. U. S. Geol. Survey. 1888.
‡Iddings: Amer. Jour. Science. 1890. XL. p. 75.
§Iddings: Amer. Jour. Science. 1891. XLI. p. 39.
‖ A. Lacroix: C. Rendu. CXXV. 1897. p. 1189.

3. Modifications due to contact with other rocks, and consequent absorption of foreign elements.

The first type is characterized by a change in the texture of the rock, which, from granitoid, becomes very coarsely ophitic, and, with porphyritic variations, may change further to finely ophitic, and even finally to glassy texture. This requires no change in the mineralogical or chemical composition, and is ordinarily accompanied by no such change.

The second type is characterized by a marked difference in the relative abundance of the constituent minerals, though no new minerals appear. That is, chemically, as well as mineralogically, the change is not qualitative, but quantitative, though in the extreme types one or more of the essential minerals of the normal gabbro may lack entirely.

The third type is characterized by the appearance of new minerals, and, often, the disappearance of old ones; thus the mineralogical nature of the rock may be wholly transformed; this transformation may render the rock more acid or more basic; it may make it highly aluminous, or richly ferriferrous: in short this change is much more varied in its effects than either of the other two, and can change the composition of the rock in nearly any conceivable way; and the transformation, both chemically and mineralogically, may be, and usually is, qualitative as well as quantitative. This change is often, but not necessarily, accompanied by a change in the texture of the rock, the resultant texture being often poikilitic, and usually fine grained.

First type of variation. —If this kind of variation be considered more in detail, it is found that the coarse granular texture of the olivine gabbro (see plate VIII, figure 1) changes by insensible degrees (see plate VIII, figure 2) until it becomes clearly ophitic, (plate IX, figure 2) without any change in the mineralogical composition, and with no appreciable changes in the chemical composition. Similar series exist from the olivine-free gabbro to the diabase containing no olivine, and could probably be found between the granular and ophitic representatives of the other varieties. Nearly all observers agree that these variations are equally imperceptible and gradual in the field. This change in texture produces very little change in external appearance, and is detected only with difficulty unless

the diabase becomes porphyritic, or fine grained, as frequently happens.

Second type of variation. The normal type of the family, i. e., the olivine gabbro, is composed of nearly equal parts of leucokratic elements (labradorite) and melanokratic elements (pyroxene and olivine). It presents variations of two categories:

1. Variations without loss of equilibrium between the leucokratic and melanokratic elements.

$$\left.\begin{array}{l}\text{Olivine}\\ \text{Gabbro}\end{array}\right\}\ \text{Labradorite} = \left\{\begin{array}{ll}\text{Pyroxene} & = \text{o — Troctolyte}\\ \text{Olivine} & = \text{o — Normal Gabbro}\end{array}\right.$$

2. Variations with loss of equilibrium.

$$\left.\begin{array}{l}\text{Olivine}\\ \text{Gabbro}\end{array}\right\}\ \begin{array}{l}\text{Labradorite} = \text{o—Peridotyte (melanokratic type)}\\ \text{Pyroxene, Olivine} = \text{o—Plagioclasyte (leucokratic type)}\end{array}$$

The decrease of the pyroxene and the increase of the olivine produce a rock which differs from the olivine gabbro in exterior characters in that it is heavier and usually darker in color, being very dark green. Its alteration produces a rusty green or a dark brown color. Sometimes the pyroxene persists in the form of narrow borders about other minerals, and may even present a more perfect development occasionally. It then encloses the olivine grains, and thus presents the poikilitic texture. But the granitic texture is much more abundant, and the rock is often a little finer grained than the normal type. Magnetite is rare as a primary mineral; a large part of the iron content of the rock is contained in the olivine, whose richness in iron is attested by the abundance of secondary magnetite. Apatite seems to have disappeared from the rock, but this absence may be merely accidental, or only local. This type is the *troctolyte.*

The reduction of the olivine and the increase of the pyroxene produce a rock which is less common than the troctolyte in northern Minnesota, whereas in other gabbro areas the reverse is usually the case. The resultant rock is a granular aggregate of labradorite and pyroxene with more or less magnetite and apatite. It is the *normal gabbro.*

The decrease of the labradorite and the increase of the

pyroxene and olivine lead to the melanokratic type, *peridotyte*, which is very rare, and no specimen has been available for this study.

When the labradorite increases in abundance, the rock becomes generally of a lighter color, the specific gravity diminishes, and the grain increases in coarseness. At the same time the olivine seems to disappear entirely, while the pyroxene becomes so rare that one can scarcely find it without the microscope. The relative amount of magnetite and of apatite may rest about the same, or decrease somewhat. Fresh fractures present many large cleavage faces of feldspar which are bright and transparent, and very often show the fine striations characteristic of the albite twinning. It is thus that the gabbro changes to *plagioclasyte*, the leucokratic type of the gabbro group. This rock, which is very abundant in large areas in America, and notably in northern Minnesota, constitutes generally only a mineralogical accident in the European gabbro regions.

Third type of variation. The origin of the *quartz gabbro* is somewhat obscure, but in all probability it may be classed among the products of contact metamorphism.

In external characters the quartz gabbro is markedly less firm, and more easily crumbled. It has a lighter color and a distinctly lower specific gravity. The texture remains unaltered, but the grain may increase in size, or porphyritic varieties may appear. Besides the minerals of the normal gabbro, quartz and zircon occur as primary constituents. The mineralogical and chemical composition is thus changed both quantitatively and qualitatively. This is the acid extreme of the series studied. The pyroxene, as noted, has entirely disappeared. The feldspar being an andesine, is more acid than in the gabbro. It is often much altered. A nearly amorphous bowlingite is the present representative of the original olivine. Magnetite probably occurred in small amount as an original constituent, but that which is now present seems to have had a secondary origin. Apatite occurs in unusually large crystals, but sparsely distributed. Calcite and rutile occur as secondary products.

It is possible that the *orthoclase gabbro* is the result of the

digestion by the gabbro magma of a slight proportion of a rock more acid and potassic.

In exterior characters the rock is at once distinguished by the red color of the orthoclase—a color due to numberless included hematite particles. It has a columnar structure only rarely found in the ordinary gabbro. The hornblende occasionally gives the rock a dark green color. The texture is still granitic, and usually of very coarse grain.

The orthoclase is the characteristic mineral, distinguishing the rock from the normal gabbros. The pyroxene has a remarkably small optic angle; it has in many cases been transformed to hornblende. Magnetite is very rare as a primary constituent, occurring ordinarily only in very small grains. As a more recent mineral it is commoner in large crystals and masses. Apatite occurs both as very large crystals, usually corroded and full of inclusions, and often biaxial, and as very minute well formed crystals, uncorroded and showing few inclusions. The latter are considered to represent the recrystallized phosphate derived from the corrosion of the former. This rock has also been termed hornblende gabbro, but it is clear that the hornblende is wholly derived from the alteration of the pyroxene. The alteration has progressed more rapidly in the orthoclastic type than in the normal gabbro on account of the presence of innumerable inclusions in the former, rendering it highly porous.

Finally, one of the most remarkable types of the series is the *cordierite noryte* which is considered to be an endomorphic state of the gabbro. The field relations indicate it, and the microscopical and chemical study add many arguments in favor of this theory.

The rocks which have been styled "muscovadyte" by the Geological and Natural History Survey of Minnesota, lithologically often belong to a series which forms the contact zone, and they are terms of passage from the gabbro on one side, to the schists on the other. These contact rocks are nearly always very fine grained. Beginning with the unmodified gabbro, the important types known to occur frequently are: gabbro, noryte, cordierite noryte, "greenstones."*

* This is the same as the series found by Lacroix at Pallet. In Minnesota there exist all the intermediate types, e. g. between gabbro and noryte there are hypersthene gabbros, and augite norytes.

The first noticeable external change is in the coarseness of grain, which becomes much reduced and is very fine in most of the norytes, and cordierite norytes. In the former the texture usually remains granitoid, but in the latter it becomes poikilitic. The color of the rock becomes more uniform on account of the fine texture, and is often slightly darker gray, or green. The specific gravity remains practically constant, but the rock becomes exceedingly tough, and difficult to break. Nevertheless, it alters much more readily than the true gabbro, and quickly changes to a crumbling mass of very fine grains. This is largely due to the fact that cordierite is a very unstable mineral, and its alteration products are found much oftener than the fresh mineral.

Microscopically, the first change from the normal gabbro type is the appearance of hypersthene, or enstatite, which gradually replaces the augite. At the same time the texture becomes much finer, and chrysolite is often replaced by fayalite, or may disappear entirely. Biotite is nearly always one of the new minerals. The feldspar may become slightly more acid. When this change is complete the noryte type is reached. Quartz norytes occasionally occur.

The next step is the appearance of cordierite, which is always in very fine rounded grains or crystals. In this type the olivine is absent; the pyroxene is enstatite or bronzite in small spheroidal masses. Biotite is abundant, enclosing the cordierite and enstatite grains. The feldspar is an acid labradorite, or even andesine, but may become rather uncommon; quartz commonly occurs, and may be abundant. The accessory minerals are numerous and include: magnetite, pyrite, apatite, zircon, epidote, staurolite, spinel, and probably graphite. Anthophyllite is a notable alteration product.

In résumé this comparative study makes it evident that the rock types studied can be grouped in the following way:

Typical normal rock—Olivine gabbro.

I. Variations due to conditions of solidification.

$\left.\begin{array}{l}\text{Intrusive.—Coarse olivine diabase.}\\ \text{Dykes, etc.—Fine diabase to basalt.}\end{array}\right\}$ porphyritic varieties.

II. Variations due to differentiation or to the original heterogeneity of the magma.

A. Replacement of the ferromagnesian minerals one by the other.

1. Pyroxene replaced by olivine.—Troctolyte.
2. Olivine replaced by pyroxene.—Normal gabbro.

B. Replacement of the leucokratic and melanokratic elements one by the other.

1. Melanokratic type.—Peridotyte.
2. Leucokratic type.—Plagioclasyte.

III. Modifications due to contact metamorphism.

1. Digestion of aluminous sediments.—Cordierite noryte.
2. Digestion of siliceous schists or quartzytes.—Quartz gabbro.
3. Digestion of a potassic rock.—Orthoclase gabbro.

Finally the *silicoferrolyte* seems to represent a sedimentary rock entirely re-crystallized under the exomorphic actions of the gabbro rather than an integral part of the latter. The silicoferrolyte differs from the gabbro from every point of view: it is much more dense, with a very dark color. After magnetite, the mineral by far the most abundant is fayalite which occurs in large, irregular masses, enclosing large grains of magnetite, and being itself surrounded partially or wholly by pyroxene. Many rounded grains of quartz are enclosed by all these minerals (more rarely by the magnetite). Thus the texture has changed from granitic to poikilitic, though the fayalite masses are mutually xenomorphic.

Comparative Mineralogy. The minerals which occur in the rock series here studied are the following:

Quartz	Tremolite	Magnetite
Orthoclase	Hornblende	Hercynite
Andesine	Chrysolite	Hematite
Labradorite	Fayalite	Göthite
Cordierite	Epidote	Ilmenite
Muscovite (Sericite)	Allanite	Limonite
Biotite (Anomite)	Penninite	Pyrite
Enstatite	Clinochlore	Rutile
Bronzite	Antigorite	Staurolite
Diopside (Pigeonite)	Bowlingite	Graphite
Augite	Apatite	Calcite
Pectolite	Titanite	Mesolite
Anthophyllite	Zircon	Scolecite
Actinolite	Spinel	Pseudomesolite

And one or two unknown minerals.

The primary minerals are:

Quartz	Allanite	Spinel
Orthoclase	Enstatite	Zircon
Andesine	Bronzite	Magnetite
Labradorite	Diopside	Hercynite
Cordierite	Augite	Staurolite
Apatite	Chrysolite	Graphite
	Fayalite	

The other minerals are secondary. Quartz and magnetite are often secondary. Anomite is of primary origin in the cordierite noryte. Cordierite, fayalite, hercynite, staurolite, spinel, and graphite are minerals especially common in regions of metamorphism.

Quartz occurs only as a secondary mineral in the normal gabbros, where it is rare. Its presence in certain types is therefore evidence of some modifying influence, which seems in the cases studied to be the absorption of pre-existing rocks.

Orthoclase is the characteristic mineral of the orthoclase gabbro. It is crowded full of inclusions, especially hematite, which give the rock its peculiar reddish color.

Andesine occurs only in those types showing a tendency to become more acid than the normal gabbro. It is rare in the gabbro unmodified by contact. In the most acid type of the series (the quartz gabbro), it is the only feldspar found. It occurs in subordinate amount in the cordierite noryte and in the orthoclase gabbro.

Labradorite is certainly the most abundant mineral in the series of rocks studied; it constitutes the larger part of the gabbros, and is lacking only in the silicoferrolyte, which contains no feldspar, and in the quartz gabbro, where it is replaced by andesine. It is so nearly pure in the plagioclasyte as to furnish excellent material for detailed study. Most briefly expressed, the chief results obtained are:

Chemical Composition.	Refringence and Birefringence.	Extinction angles.	Cleavage angle.	Acute Bisectrix.
SiO_2 53.38			$pg^1(001)\wedge(010)$	
Al_2O_3 29.70	$n_g = 1.5705$	Sn_g -37°	=94°16′	n_g
Fe_2O_3 .21	$n_m = 1.5660$	Tn_p 57½°		
MgO trace	$n_p = 1.5626$			Dispersion about n_g
CaO 11.90	N = 1.566	Parallel to $p(001)$ 12°	Optic angle	
Na_2O 4.30	$n_g - n_m = .0046$	Parallel to $g^1(010)$ 26°		
K_2O .56	$n_m - n_p = .0036$		$2V_{Tl} = 83°29'$	
H_2O .37	$n_g - n_p = .0082$	Maximum equal extinction angle in zone perpendicular to $g^1(010)$ -38°	$2V_{Na} = 83°47'$	$\rho > \upsilon$
100.42			$2V_{Li} = 84°9'$	
Sp. Gr. 2.701				

The chemical composition does not differ essentially from that expressed by the formula Ab_3An_4. The feldspar Ab_3An_4 has been studied much less than the plagioclase $Ab_1 An_1$. Its crystallographic characters have never received adequate attention, the great majority of the measures heretofore made on labradorite having been obtained from material of the composition Ab_1An_1, or $Ab_7 An_8$. It is for this reason that the crystallographic measures, though necessarily less exact in proportion to the total possible variations, are of unusual interest. Moreover, they present a value for the angle *pg*¹ (100) ∧ (010) which is larger than 94° 10′, the value of this angle in anorthite, and the supposed limiting value according to the theory of Tschermak. In this connection it is shown that the angle *pg*¹ (001) ∧ (010) increases with remarkable rapidity as the labradorite becomes more basic, and both extremes of the labradorite series seem to show values at variance with the theory of Tschermak. This appears not only from the measures made by the author on a series of labradorites from various localities, but also from a critical examination and comparative study of all the measures of the angle *pg*¹ (001) ∧ (010) heretofore made on labradorite whose exact composition was determined.

The measures of the indices of refraction show that a distinct increase occurs between Ab_1An_1 and Ab_3An_4, in perfect harmony with the values obtained, and the steady increase shown by all the members of the plagioclase series, as the basicity increases. The values obtained are, moreover slightly greater than those obtained from the same mineral derived from the volcanic rocks. The direct measure of the birefringence likewise shows a slightly greater value than that in labradorite of the volcanic rocks. But these differences are wholly negligible when compared with the difference in the optic angle, which is about 6° greater in the Minnesota feldspar than in the labradorites of the same composition from volcanic rocks studied by Fouqué. Therefore, there seems to exist certain differences in the character of the mineral in the two series of rocks.

Cordierite occurs in only one rock of the series; but in that it is abundant and characteristic. Its presence is very significant as it indicates an unusual chemical condition, and fur-

nishes good evidence as to the origin of the rock. It is here reported for the first time in a granular basic rock of the labradoritic series. Its twinning is characteristic when all other methods of distinction fail. Cordierite contains many inclusions of magnetite, often coated with spinel, of liquids, and finally of staurolite. The last is oriented definitely in its host. But no pleochroic halos occur.

Muscovite only occurs as a product of alteration, and is very rare on account of the fresh condition of the rocks.

Biotite occurs as a primary mineral in only one type, the cordierite noryte, in which the optic properties prove the existence of the unusual variety, *anomite*. In some of the gabbros and diabases biotite is not uncommon, but it seems to be invariably of secondary origin (often mesogenetic) in these cases. Pleochroic halos in biotite are an interesting subject of study.

Bronzite and *enstatite* occur in only one rock, the cordierite noryte. Their presence is due to a lack of calcium in the rock.* Bronzite greatly predominates. They illustrate a new type of uralitization in their alteration to anthophyllite.

Diopside (*Pigeonite*) is not known to occur except in the olivine diabase from Pigeon point, though a similar mineral exists in the orthoclase gabbro. In the former rock it presents most remarkable anomalies, consisting essentially of a very small, but variable value of the angle of the optic axes, though the pyroxene presents no peculiarities in its chemical composition except an unusual richness in titanium.

Augite, with its modified form *diallage*, occurs not infrequently in the Minnesota diabases and gabbros, and in very small quantity in the plagioclasytes, troctolytes, and silicoferrolytes. In the modified types, such as the orthoclase and quartz gabbros, the augite is much altered, producing hornblende, biotite, chlorite, etc. Augite, as well as diallage, often shows brownish lamellar inclusions, considered to be of primary origin.

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*The remarkable rock (from near Harrismith, Orange Free State) described by M. Molengraaf (Jahrb. k. preuss. geol. Landesanst. Berlin, 1877, p. 44) apparently presents an exception in both these particulars. It is essentially composed of a glassy groundmass rich in crystals of cordierite and spinel with small crystals of augite (?) and magnetite.

Pectolite occurs in small quantity in only one type, the olivine gabbro, where it is clearly derived from the direct decomposition of the feldspar.

Anthophyllite is another secondary product; it is derived from the enstatite or bronzite of the cordierite noryte. All stages of the transformation occur, from the compact pyroxene to the fibrous or lamellar amphibole. The two minerals often have a common orientation, and simultaneous extinction. Anthophyllite contains rather feeble, greenish pleochroic halos about inclusions of zircon.

Actinolite and *tremolite* are rare alteration products found in the silicoferrolyte and orthoclase gabbro.

Hornblende is abundant in the orthoclase gabbro; in the ordinary gabbros and diabases it is rare; in the other types it is wanting, though it probably existed at one time in the quartz gabbro. It is secondary in all these rocks.

Allanite, as well as apatite, sometimes causes pleochroic halos in hornblende.

Chrysolite occurs in the gabbros and diabases; it is the most abundant mineral of the troctolyte; in the silicoferrolyte it is replaced by fayalite; in the quartz gabbro, it is only represented by rare masses of bowlingite, nearly amorphous; in the plagioclasyte, orthoclase gabbro, and cordierite noryte it is entirely wanting. It seems to be highly ferriferous, the ratio Fe : Mg varying from about 1 : 1.4 in the olivine gabbro to 1 : .8 in the olivine diabase, and the mineral is thus even too rich in iron for typical hyalosiderite. It is said to be replaced occasionally by fayalite, even in the gabbros.

Fayalite occurs only in the silicoferrolyte, where it is abundant. The optic properties alone, notably the negative sign of the bisectrix and the smaller angle of the optic axes distinguish it from chrysolite. The cleavages are more conspicuous than in unaltered chrysolite.

Epidote occurs very rarely in the cordierite noryte, where it seems to be of primary origin. It occurs still more rarely in the orthoclase gabbro, and in the quartz gabbro, where it is undoubtedly secondary.

Allanite occurs in the Pigeon point diabase, and very rarely in some samples of the normal gabbro; it forms small crystals, sometimes rounded or irregular. In color and pleochroism,

as well as in birefringence, the mineral is quite variable. It causes intense pleochroic halos in all the colored minerals in which it has been observed.

Penninite occurs in small amount in every type studied, except the orthoclase gabbro and the cordierite noryte. It is most abundant in the most highly altered type, the quartz gabbro, where the positive and negative varieties both occur. It is derived from the alteration of the original ferromagnesian element of the rock, which was probably a pyroxene.

Clinochlore occurs in every type except the cordierite noryte, quartz gabbro, and troctolyte; thus the only type containing no chlorite is the cordierite noryte. The pleochroism of clinochlore is very similar to that of positive penninite. Clinochlore is usually positive. It is derived from the alteration of pyroxene, or some other ferromagnesian mineral. It seems to occur sometimes as an alteration product of feldspar.

Antigorite is rare in Minnesota gabbros, but occurs sparingly in the normal gabbros, and in the diabases. It is formed from the decomposition of olivine, but is usually deposited away from the olivine grains in the fractures (and cavities, if any exist) in the surrounding minerals.

Bowlingite is comparatively abundant, and is beautifully developed in the olivine diabase from Pigeon point, where it is perfectly crystallized, and often oriented on the olivine. It is formed also from fayalite in the silicoferrolyte.

Apatite occurs in every type, except the troctolyte and silicoferrolyte, but it is abundant only in the orthoclase gabbro and quartz gabbro.

Titanite occurs as a decomposition product in the olivine diabase and in the orthoclase gabbro.

Zircon has not been found in the normal gabbros, nor in any of their unmetamorphosed forms; it occurs only in the endomorphosed types, such as the cordierite noryte, and the quartz gabbro. In these rocks it occurs in the usual, small, square prisms which determine intense halos in penninite and biotite and feebler ones in anthophyllite.

Spinel occurs only as a thin coating over the magnetite, when it is surrounded by cordierite. It is probably the variety pleonaste.

Magnetite occurs as a primary mineral in every type

studied, with the possible exception of the quartz gabbro. It forms fully one-half of the silicoferrolyte, where it is associated with another spinellid, the iron-alumina variety, hercynite. It occurs as a secondary mineral in every type, with the possible exception of the silicoferrolyte, and the cordierite noryte. It is thus the most widely disseminated mineral occurring in these gabbros.

Hercynite occurs in small amount in the silicoferrolyte. It is the result of an excess of alumina in an extremely basic (ferric) rock.

Hematite is rather common, in thin flakes and particles in the plagioclasyte and orthoclase gabbro; it is less abundant in the olivine gabbro, the diabases, and the silicoferrolyte.

Göthite is known only in the silicoferrolyte, and there occurs only rarely.

Ilmenite occurs in small quantity accompanying magnetite in the olivine diabase, and perhaps in other types.

Limonite is only known in the plagioclasyte, when highly altered.

Pyrite occurs as a primary mineral in the diabases, and in the cordierite noryte; it probably has a secondary origin in the plagioclasyte, and perhaps in part also in the olivine diabase. It is always sparsely distributed.

Rutile occurs only in the quartz gabbro, in the form of minute crystals deeply striated.

Staurolite is a mineral whose presence is not to be expected in an eruptive rock; it occurs in well formed, though microscopic crystals, as inclusions in the cordierite of the noryte. It is usually oriented with the surrounding mineral, the crystallographic axes, and the elongation of the staurolite and cordierite being parallel. Staurolite contains extremely minute inclusions, which are believed to be *graphite*.

Calcite occurs in minute quantity in every type studied except the cordierite noryte and silicoferrolyte; it is relatively very abundant in the quartz gabbro.

Mesolite occurs in the plagioclasyte only. It is derived directly from the decomposition of the labradorite.

Scolecite is likewise confined in occurrence to the plagioclasyte. Its direct derivation from the labradorite is unquestionable.

Pseudomesolite is a new zeolite occurring in the plagioclasyte. In its chemical composition it is very similar to mesolite,—that is to say, it may be considered as formed by a mixture of scolecite and of mesotype (My_5Sc_7, according to the analysis made).

It occurs in white, fibrous masses, transparent in thin section. Its optic properties differ not only from those of mesolite, but also from those of scolecite and mesotype. In pseudomesolite, for example, the optic plane is not perpendicular to the elongation as in mesolite; n_g makes an angle of about 20° with the vertical axis, and constitutes the acute bisectrix of the very small optic angle.

COMPARATIVE CHEMICAL COMPOSITION. *Methods of Analysis.* The rock analyses have all been carried out by the method of St. Claire Deville, always being made in duplicate. and averages taken. In case the results were not sufficiently concordant, a third partial analysis was resorted to by the hydrofluoric acid method.

The titanium precipitations were invariably made by prolonged boiling after fusion with acid potassium sulphate in a solution containing a little free sulphuric acid. The separation of iron and alumina was accomplished by conducting a current of hydrogen and hydrochloric acid gases mixed over the precipitates heated to redness in a platinum tube. The hydrogen gas is generated in the ordinary way ($Zn + H_2SO_4$), and conducted well below the surface of strong sulphuric acid in a vessel, above which a stoppered vessel is fastened containing pure hydrochloric acid.* The stopper is turned until the HCl drops very slowly (2-6 drops per minute) upon the sulphuric acid, which liberates pure dry HCl gas. The hydrogen, forming at the same time, and passing through the H_2SO_4, serves to keep the latter well stirred.

This arrangement has the following advantages over the ordinary alternating gas method which may be termed the Deville-Rivot method:

1. It requires less heat applied to the precipitates, a dull red being ample, and perhaps more than enough.

2. It decreases the chance of explosion of hydrogen and oxygen (from air not wholly expelled, or leakage), both on

*This arrangement was suggested to the writer by M. Arsandaux, bacteriologist in the laboratory of the préfecture of the Seine.

account of the lower heat applied, and on account of the dilution of the hydrogen with HCl gas.

3. It requires much less attention during the reaction; with the old method it is necessary to change the currents every three or four minutes; with this arrangement once started, the apparatus can be left to itself till the reaction is complete, provided the hydrogen generator will continue to act for that length of time.

4. This arrangement permits the simultaneous qualitative determination of titanic acid. This last point requires a word of explanation. Titanic acid (TiO_2) often occurs in the form of a white powder which cannot be distinguished from alumina Al_2O_3. This powder is affected by the Deville-Rivot method, but only very slowly, and with uncertain results. Ordinarily* by this method the titanic acid is partially changed (often only a small part) to sesquioxide of titanium (Ti_2O_3), which colors the alumina a dirty gray. This is not distinct; it is only obtained after long treatment, and not characteristic, since traces of iron can produce practically the same color. On the other hand, by the method described above the titanic acid is changed to the intermediate oxide Ti_3O_4, which has a characteristic color, being dark gray or indigo blue, and reveals its presence by the tint imparted to the alumina. With 10% TiO_2 in the powder the color is very marked slate blue. However, the test is not very delicate and the results of the analyses show that it becomes rather uncertain for less than 4% of titanic acid in the powder after separation of the iron. That is, in case the alumina attains 25% of the rock, this method will reveal 1% of titanic acid. If the alumina is less, a proportionally smaller per cent of titanic acid can be detected. It should be remembered in this connection that some titanic acid can usually be found with the silica; but a large part is usually found with the iron and alumina.

As a check upon the iron determination, the iron was also determined in both its conditions by the Cooke method as modified by J. H. Pratt†, with very satisfactory results.

*But Van der Pfordten obtained TiO_2 after treatment for several hours in dry hydrogen gas at very high temperature. See Deutsch. chem. Gesellsch. 1884. I. p. 728.

†J. H. Pratt: American Journal of Science; 1894: XLVIII. p. 149.

The manganese-iron separations were made by precipitating the iron as a basic acetate in a boiling solution; less frequently by precipitating the iron by means of barium carbonate.

The water determinations were not made directly, but by loss on ignition, oxidation and reduction being avoided as far as practicable. They therefore include scarcely appreciable traces of F (or Cl) in many cases, as well as occasional traces of CO_2 and S. In the quartz gabbro the CO_2 is doubtless more important, and may reach 1.00%.

Results of the Analyses. The rock analyses scattered through the preceding pages can be grouped as follows:

	Olivine Gabbro. 1136. I.	Diabase. 954. II.	Olivine Diabase. 1843. III.	Plagioclasyte. 336E. IV.	Troctolyte. 514. V.	Orthoclase Gabbro. 1797. VI.	Cordierite Noryte. 883. VII.	Quartz Gabbro. 84G. VIII.	Silico-ferrolyte. 960. IX.
SiO_2	47.70	47.90	49.18	49.78	35.81	49.06	52.84	56.60	21.50
TiO_2	1.80	.57	1.09		2.30	1.46	Trace	1.59	Trace
Al_2O_3	19.04	19.92	19.01	29.37	14.32	15.33	23.62	17.84	8.02
Fe_2O_3	.87	4.92	.89	.34	7.38	5.92	.65	2.55	30.54
FeO	8.84	9.78	7.79	.60	15.25	11.53	10.00	4.09	33.53
MnO	Trace	Trace	.51	.08	.18	.61	.43	Trace	.32
MgO	8.65	4.55	6.42	1.01	10.49	2.75	3.16	3.16	1.95
CaO	8.96	8.56	9.12	11.86	7.23	6.80	3.92	6.28	1.55
Na_2O	2.53	2.75	3.32	4.39	2.06	3.17	2.64	4.45	.42
K_2O	.53	.56	.82	.46	.37	1.40	.67	.45	.10
H_2O	1.38	.76	2.06	1.76	5.23	1.76	1.87	3.20	2.77
P_2O_5						.27		.14	
	100.30	100.27	100.21	99.65	100.62	100.06	99.80	100.35	100.70
Sp. Gr.	2.89	2.93	2.84	2.676	3.08	2.84	2.83	2.38	4.02

I. Olivine gabbro (1136), from a point about a half a mile west of the line between Sec. 31, 62-11 and Sec. 6, 61-11, in T. 61, near Birch lake. A trace of CO_2 occurs; P_2O_5 and Fl (or Cl) also present in apatite in very small amount. No appreciable BaO, nor SrO; no other elements determined.

II. Diabase, poor in olivine (954) from the east side of Birch lake on N. W. ¼ Sec. 17, 61-11. Traces of P_2O_5, F (or Cl), CO_2, and S are shown by the mineralogical composition; no appreciable BaO, nor SrO; no other elements determined.

III. Olivine diabase (1843), from the extremity of Pigeon point. Traces of P_2O_5, F (or Cl), and the rare metals of the cerium and yttrium groups occur in apatite and allanite; no appreciable BaO, nor SrO, nor Li_2O; no other elements determined.

IV. Plagioclasyte (336E), from the summit of Carlton peak. Traces of P_2O_5 and F (or Cl), CO_2 and S occur in rare minerals of the rock; no BaO, nor SrO; no other elements determined.

V. Troctolyte (514), from near Duluth; traces of CO_2 occur in calcite (very rare): no appreciable BaO, nor SrO; no other elements determined.

VI. Orthoclase gabbro (1797), from Duluth; F (or Cl), and CO_2 are present in traces in apatite and calcite; no appreciable BaO, nor SrO; no other elements determined.

VII. Cordierite-noryte (983). from Sec. 15, 63-9, not far from Snowbank lake; traces of ZrO_2, P_2O_5, F (or Cl), S, and C (?) indicated mineralogically; no appreciable BaO nor SrO; no other elements determined.

VIII. Quartz gabbro (854G), from S. E. ¼ S. W. ¼ Sec. 12, 64-6, southwest shore of small lake, near Little Saganaga lake; F (or Cl) and ZrO_2 occur in rare minerals; the relative abundance of calcite indicates that CO_2 is in more than mere traces, and many attain 1.00 per cent; no appreciable BaO, nor SrO; no other elements determined.

IX. Silicoferrolyte (960), from a low ridge of fifteen rods from the shore, S. W. ¼ Sec. 24, 64-12, near Birch lake; no BaO, nor SrO, nor Li_2O; no other elements determined.

Of late years much attention has been directed to the chemical composition of igneous rocks, and conclusions relative to their origin have been derived from this study. Attempts have been made to coordinate magmas, to establish natural classifications, and to determine whether or not igneous rocks are derived from a single primitive magma. The writer has accepted the theory proposed by Prof. N. H. Winchell of the origin of all these rocks by a refusion of preexistent rocks. Therefore the variations in the composition of these rocks are due (at least in part) to the variations in the rocks from which they have been derived. But disregarding this hypothesis for the moment let us see what would be the relations of these rocks considered as ordinary igneous rocks, and what position they would take in the classifications heretofore proposed, etc.

The relative number of molecules and atoms of each oxide and metal are given in the following tables, as calculated from the analyses given above. Each analysis is first calculated to the scale of one hundred, after the elimination of such elements as H_2O, CO_2, and P_2O_5. The relative number of molecules of each oxide (called Z by Rosenbusch) is then obtained by dividing the per cent of the oxide by the weight of its molecule (see table II). From these values are readily obtained

the relative number of atoms of each oxide (AZ—see table III.), and the relative number of atoms of each metal (MAZ—see table IV.). Finally all these values are reduced to the scale of one hundred in the last three tables.

Table II. The relative number of molecules of each oxide. [Z. (*zahl*) of Rosenbusch.]

	Average of 1136, 954 and 1843.	Olivine Gabbro. 1136.	Diabase. 954.	Olivine Diabase. 1843.	Plagioclasyte. 336E.	Troctolyte. 514.	Orthoclase Gabbro. 1797.	Cordierite Noryte. 983.	Quartz Gabbro. 854G.	Silico-ferrolyte. 980.
SiO_2	81.38	80.38	80.23	83.52	84.77	62.55	83.42	89.93	97.25	36.58
TiO_2	1.46	2.27	.71	1.39		3.01	1.86		2.05	
Al_2O_3	19.16	18.87	19.62	18.99	29,41	14.72	15.33	23.64	18.03	8.03
Fe_2O_3	1.40	.55	3.09	.57	.22	4.83	3.77	.41	1.63	19.49
FeO	12.36	12.40	13.64	11.03	.85	22.21	16.33	14.18	5.86	47.55
MnO	.28			.73	.11	.27	.87	.62		.46
MgO	16.55	21.85	11.45	16.35	2.57	27.50	7.02	8.07	8.15	4.97
CaO	16.04	16.16	15.36	16.59	21.64	13.53	12.38	7.14	11.57	2.82
Na_2O	4.68	4.13	4.45	5.45	7.23	3.48	5.21	4 35	7.40	.69
K_2O	.68	.57	.59	.88	.50	.41	1.52	.72	.49	.11
	153.99	157.18	149.14	155.50	147.30	152.51	147.71	149.06	152.43	120.70

Table III. The relative number of atoms of each oxide. [AZ (*atomzahl*)].

	Olivine Gabbro. 1136.	Diabase. 954.	Olivine Diabase. 1843.	Plagioclasyte. 336E.	Troctolyte. 514.	Orthoclase Gabbro. 1797.	Cordierite Noryte. 983.	Quartz Gabbro. 854G.	Silico-ferrolyte. 980.
SiO_2	247.95	242.82	254.73	254.31	196.68	255.84	269.79	297.90	109.74
Al_2O_3	94.35	98.10	94.95	147.05	73.60	76.65	118.20	90.15	40.15
Fe_2O_3	27.55	42.73	26.37	3.02	69.11	53.25	31.65	19.87	193.47
MgO	43.70	22.90	32.70	5.14	55.00	14.04	16.14	16.30	9.94
CaO	32.32	30.72	33.18	43.28	27.06	24.76	14.28	23.14	5.64
Na_2O	12.39	13.35	16.35	21.69	10.44	15.63	13.05	22.20	2.07
K_2O	1.71	1.77	2.64	1.50	1.23	4.56	2.16	1.47	.33
	459.97	452.39	460.92	475.99	433.12	444.73	465.27	471.03	361.34

Table IV. The relative number of atoms of each metal, [MAZ (*metallatomzahl*)].

	Olivine Gabbro. 1136.	Diabase. 954.	Olivine Diabase. 1843.	Plagioclasyte. 336E.	Troctolyte. 514.	Orthoclase Gabbro. 1797.	Cordierite Noryte. 983.	Quartz Gabbro. 854G.	Silico-ferrolyte. 980.
Si,(Ti)	82.65	80.94	84.91	84.77	65.56	85.28	89.93	99.30	36.58
Al	37.74	39.24	37.98	58.82	29.44	30.66	47.28	36.06	16.06
Fe,(Mn)	13.50	19.82	12.90	1.40	32.14	24.74	15.62	9.12	86.99
Mg	21.85	11.45	16.35	2.57	27.50	7.02	8.07	8.15	4.97
Ca	16.16	15.36	16.59	21.64	13.53	12.38	7.14	11.57	2.82
Na	8.26	8.90	10.90	14.46	6.96	10.42	8.70	14.80	1.38
K	1.14	1.18	1.76	1.00	.82	3.04	1.44	.98	.22
	181.30	176.89	181.39	184.66	175.95	173.54	178.18	179.98	149.02

Table V. The relative number of molecules of each oxide, (Z), on the scale of one hundred.

	Olivine Gabbro. 1136.	Diabase. 954.	Olivine Diabase. 1843.	Plagioclasyte. 336E.	Troctolyte. 514.	Orthoclase Gabbro. 1797.	Cordierite Noryte. 983.	Quartz Gabbro. 854G.	Silico-ferrolyte. 980.
SiO_2	51.14	53.79	53.71	57.55	41.01	56.47	60.33	63.80	30.31
TiO_2	1.44	.48	.90		1.97	1.26		1.34	
Al_2O_3	12.01	13.15	12.21	19.97	9.65	10.38	15.86	11.83	6.65
Fe_2O_3	.35	2.07	.37	.15	3.17	2.55	.28	1.07	16.15
FeO	7.89	9.15	7.09	.58	14.57	11.06	9.51	3.84	39.40
MnO			.47	.07	.18	.59	.42		.38
MgO	13.90	7.68	10.51	1.74	18.03	4.75	5.41	5.35	4.12
CaO	10.28	10.30	10.67	14.69	8.87	8.38	4.79	7.59	2.33
Na_2O	2.63	2.98	3.50	4.91	2.28	3.53	2.92	4.86	.57
K_2O	.36	.40	.57	.34	.27	1.03	.48	.32	.09
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table VI. The relative number of atoms of each oxide (AZ) on the scale of one hundred.

	Olivine Gabbro. 1136.	Diabase. 954.	Olivine Diabase. 1843.	Plagioclasyte. 336E.	Troctolyte. 514.	Orthoclase Gabbro. 1797.	Cordierite Noryte. 983.	Quartz Gabbro. 854G.	Silico-ferrolyte. 980.
SiO_2	53.91	53.68	55.27	53.43	45.41	57.53	57.99	63.24	30.37
Al_2O_3	20.51	21.68	20.60	30.89	16.99	17.21	25.41	19.15	11.11
Fe_2O_3	5.99	9.45	5.72	.63	15.96	11.98	6.80	4.22	53.55
MgO	9.50	5.06	7.09	1.08	12.70	3.16	3.47	3.46	2.75
CaO	7.03	6.79	7.20	9.09	6.25	5.57	3.07	4.91	1.56
Na_2O	2.69	2.95	3.55	4.56	2.41	3.52	2.80	4.71	.57
K_2O	.37	.39	.57	.32	.28	1.03	.46	.31	.09
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table VII. The relative number of atoms of each metal (MAZ), on the scale of one hundred.

	Olivine Gabbro. 1136.	Diabase. 954.	Olivine Diabase. 1843.	Plagioclasyte. 336E.	Troctolyte. 514.	Orthoclase Gabbro. 1797.	Cordierite Noryte, 983.	Quartz Gabbro. 854G.	Silico-ferrolyte. 980.
Si(Ti)	45.59	45.76	46.81	45.91	37.26	49.14	50.47	55.17	24.55
Al	20.82	22.18	20.94	31.85	16.73	17.67	26.53	20.04	10.78
Fe(Mn)	7.45	11.21	7.11	.76	18.26	14.26	8.77	5.07	58.37
Mg	12.05	6.47	9.01	1.39	15.63	4.05	4.53	4.53	3.33
Ca	8.91	8.68	9.15	11.72	7.69	7.13	4.01	6.43	1.89
Na	4.55	5.03	6.01	7.83	3.96	6.00	4.88	8.22	.93
K	.63	.67	.97	.54	.47	1.75	.81	.54	.15
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Application of the different methods of graphic representation of the chemical composition of igneous rocks. Several petrographers have recently attempted to represent graphically the chemical composition of various rocks. The diagrams obtained by the diverse methods proposed have certain advantages and certain disadvantages. It will not be

without interest to apply these methods to the results of the analyses given, and to show what relations each method puts particularly in relief in the special cases considered.

The method proposed by Michael Lévy*has the advantage of giving a diagram for each rock, and may be employed therefore not only for a petrographic series, whose various types may readily be compared, but also for any rock considered alone. The method of Brögger is a modification of the preceding, which loses some of the advantages of Michael Lévy's method, particularly in the case of some of the rocks here considered.

The methods of Becke and of Iddings adapt themselves to a less general usage than the preceding methods, since they are destined to present the characteristics of a series of rocks, and, in certain cases, its continuity, but not of any rock considered alone.

The method of Michael Lévy may be considered in detail first, as it is more particularly suggestive for certain purposes of special importance in the present instance.

According to this method the various elements K, Na, Ca, Mg, and Fe, in the form of their oxides, as found in the analysis, are inscribed on two rectangular axes in the following way: the potassium oxide (k) is represented on the negative ordinate, the sodium oxide (n) on the positive abscissa, the calcium oxide entering into the composition of the feldspar (c) on the positive ordinate; and thus we have the summits of the "alkaline-earth" triangle (knc), or in most cases, the feldspathic triangle. The oxide of magnesium (m) is represented on the positive ordinate, the excess of calcium oxide (c') on the negative abscissa and the oxides of iron (f and f') on the negative ordinate, and the summits of the ferromagnesian triangle ($mc'f$) are thus fixed. This triangle is tinted in black.

It will be noted that two important elements, Si and Al, remain unrepresented; the silica is provided for by inscribing the numerical per cent on the horizontal axis; the alumina as a whole is never directly represented, but if an excess of alumina (a = alumina not combined in the form of feldspars) oc-

*Michel Lévy: Classification des Magmas des Roches Eruptives: Bull. Soc. Geol. Fr. 1897, XXV. pp. 326-376.

curs, it is represented as a positive, instead of negative abscissa, taking the place in the ferromagnesian triangle of the nonfeldspathisable calcium oxide (c'), which evidently cannot exist.

The "excess of alumina" is determined as follows: The potassium oxide is combined with alumina in the feldspars according to the formula KAl. This alumina,* which may be obtained by multiplying the per cent of K_2O by 1.085 may be called *Alk*; no rocks are known containing less alumina than *Alk*, that is, containing an excess of potassium. The sodium oxide is combined with alumina in the feldspars according to the formula NaAl, and this alumina, obtained similarly from the per cent of sodium oxide by using the multiplier 1.625, can be called *Aln*; alumina less in amount than $Alk + Aln$ is known only in acid rocks (e. g., certain syenytes, pantellerytes, etc.)† The calcium oxide in the feldspars is combined according to the formula $CaAl_2$; this alumina, obtained by affecting the per cent of calcium oxide with 1.825 as a factor, may be called *Alc*; alumina less in amount than $Alk + Aln + Alc$ is the general rule in all igneous rocks,‡ and the excess of calcium oxide (c') becomes very notable in the basic and ultra-basic rocks. The excess of alumina (a) is found from the equation§: $m Al_2O_3 - (Alk + Aln + Alc) = a$. But as just noted this excess is rare; usually it is necessary instead to determine the amount of calcium oxide which will saturate the alumina after deduction of *Alk* and *Aln*. This may readily be obtained from the equation: $c = .548[m Al_2O_3 - (Alk + Aln)]$ Then, evidently: $c' = m CaO - c$. To distinguish between FeO and Fe_2O_3 Lacroix ‖ proposes to call f' the per cent. of FeO, and f that of Fe_2O_3. The summit of the triangle remains at f while f' is indicated by a mark in the negative ordinate.

*Cf. Lacroix: Le Gabbro du Pallet: Service Carte Geol. Fr. Bull. 67. 1899, p. 24.

†In this case the excess of alumina (a) as well as the feldspathisable calcium oxide (c), inevitably lack; the excess of sodium oxide (n) is represented as a negative abscissa, but is laid off from a point on the axis y a little above the axis x.

‡The most important exception is among the granites, where the micas frequently cause an excess of alumina.

§Inversely the total alumina can evidently be obtained from the diagrams from the equation $x Al_2O_3 = 1.825c + 1.625n + 1.085k + a$; a usually being zero.

‖A. Lacroix: loc. cit. p. 25.

The scale adopted by M. Michel Lévy is two millimeters for one per cent; it is too small to properly represent the amount of potassium oxide found in many basic rocks, but as a larger scale would in some cases produce a diagram too large, the same scale is employed in the diagrams. (See plate XIII).

An examination of the diagrams constructed according to the rules just established and based on the values furnished by the analyses will show at once that the olivine gabbro (Plate XIII., Fig. 3) and olivine diabase (Fig. 6) can be considered together, being nearly identical in all respects. They are rather basic rocks as shown by the slight development of the feldspathic triangle below the axis x, and the dominant feldspar is labradorite, as shown by the ratio: CaO : Na_2O. They are not saturated with alumina but the calcium excess (c') is small; the magnesia is approximately equal to the calcium of the feldspars. Both types are rich in feldspar, as shown by the relative area of the two triangles.* The ratio K_2O : Na_2O varies only slightly from 1 : 5 to 1 : 4. The only differences to be detected are: First, the feldspar elements are a trifle more abundant in the olivine diabase; second, the magnesia and iron oxides are a trifle less, and the calcium excess a trifle greater in the ophitic type. The diabase (Fig. 4) belongs to the same group, and differs only in showing less magnesia and more iron, corresponding to a decrease in the amount of the olivine. The ratio K_2O : Na_2O remains 1 : 5, and the feldspar is labradoric. These types mineralogically certainly belong to the gabbro family and are derived from the magma called "diorito-diabasic" by Michel Lévy (except the diabase (954), which is from the "granito-esterellic" magma), that is, a magma in which the calcium oxide of the feldspars is in large amount, but is approximately equaled by the magnesia, while the potassium oxide is nearly wanting. On the contrary they present the inequality, Fe + Mg > Ca + Na + K, which is characteristic of the peridotyte magma (π), of Rosenbusch, though at the same time they present the character of his gabbro magma (ψ), namely, Ca > Na + K, Si >

*This is more evident when it is noted that the maximum area of the feldspar triangle (cf. plate XIII, Fig. 7) does not exceed one-fourth to one-sixth of the maximum area of the ferromagnesian triangle (cf. Fig. 10.)

(Ca + Fe + Mg), and Mg < Ca + Na + K. They belong to the fourth class of Lang, having a predominance of CaO over $Na_2O + K_2O$; and to the type having $Na_2O > K_2O < CaO < 3Na_2O + 3K_2O$. They possess neither the characteristics of his Diorite-Diabase type nor of his Gabbro-Dolerite type. These three types present the characters of the group called "melanokrate" by Brögger *: that is, they have a predominance (by weight) of the ferromagnesian silicates, and belong to the calcic sub-group ("calcicoplete").

The plagioclasyte (Fig. 7) shows evidence of its purity as simple labradorite feldspar by the absence of the ferromagnesian triangle; indeed, the calcium excess no longer exists; the rock is saturated with alumina, but the excess of alumina ($a = .09$) is too slight to permit representation. The triangle of basic elements is thus reduced to the very short ferro-magnesian line. The ratio $K_2O : Na_2O$ has noticeably changed, and is nearly 1 : 10; this is due to an increase in the sodium without a corresponding increase in the potassium. It is interesting to note that this plagioclasyte belongs to the granitic magma of Michael Lévy, being rich in calcium(and alumina; $a = 0$, $c' = 0$), and poor in magnesia and potassium. On the contrary it is derived from the gabbro magma of Rosenbusch since Ca > Na + K, while Mg + Fe < Ca + Na + K and Si < Ca + Fe + Mg. According to Lang's classification this rock belongs with the three preceding types. On the other hand it represents Brögger's second grand division, namely, the "leukokrate," since the alkaline-earthy aluminous silicate labradorite greatly predominates.

The troctolyte on the contrary (Fig. 2) shows a notable development of the ferromagnesian triangle, and since pyroxene occurs only in very small amount the ratio $m : f$ very approximately indicates the composition of the olivine. The ratio $c : n$ shows that the feldspar is again labradorite; the ratio $k : n$ still remains nearly 1 : 5. This rock also belongs with the preceding types according to Lang. It represents the peridotyte magma (π) of Rosenbusch, showing none of the characters of his gabbro magma (ψ), though it is certainly a gabbro in mineral composition. It seems to represent the

*W. C. Brögger: Das Ganggefolge des Laurdalits, 1898. p. 258 et seq.

"nephelino-kersantitic" magma of Michel Lévy. It is a good example of the melanokrate series of Brögger.

The orthoclase gabbro (Fig. 5) is the only rock of the series possessing an appreciable development of the feldspar triangle below the x axis—this is its chief characteristic, and translates the presence of the orthoclase. The ratio $K_2O:Na_2O$ is therefore changed, but scarcely equals 1 : 2. The ratio $c:n$ indicates that the feldspar is a very acid labradorite with even perhaps some andesine. CaO still predominates over Na_2O and K_2O, but the metals Na + K slightly exceed Ca. It is a type which does not fall naturally under any of Rosenbusch's magmas, having some of the characters of the granitic-dioritic magma (σ), the gabbro magma (ψ) and the peridotyte magma (π). It is another example of the granito-esterellic magma of Michel Lévy, and as such it is to be compared with the diabase (954). The orthoclase gabbro belongs to the melanokrate series of Brögger, but differs from the preceding types since it belongs to the alkaline division. This rock belongs to the diorite-diabase type of Lang's calcic class.

The quartz gabbro (Fig. 9) is markedly more acid than any other rock of the series. Its chief characteristic does not, therefore, appear from the diagrams so strikingly as in other cases. However, it is to be noted that the size of the two triangles is in general a measure of the basicity, and we see that the figure is the smallest of the series. The ratio $c:n$ shows that the feldspar is more acid than the prevalent labradorite, being chiefly andesine. The excess of calcium oxide (c') is very slight, and this, together with the low content of iron and magnesia, makes the present composition of the rock correspond to that of a leukokrate. The ratio $K_2O:Na_2O$ is very low—1 : 10, and, as in the plagioclasyte, this is caused by an increase in the sodium oxide rather than by a decrease in the potash. The rock is clearly derived from the granito-dioritic magma of Rosenbusch. It furnishes a third example of the granito-esterellic magma of Michel Lévy, of the diorito-diabasic type; and belongs to the norite-dolerite type of Lang's calcic class.

The cordierite noryte is a rock entirely peculiar. The great excess of alumina, so strikingly exhibited by the diagram (Fig. 8), shows that it represents a type unknown until

very recently among basic granular rocks. In fact, no rock of this kind is mentioned in the classifications of magmas of the authors cited. The only analogous rocks from this point of view, but different in certain respects, are, as already noted, the cordierite noryte of Pallet, France, described by Prof. A. Lacroix, and certain exceptional rocks, which, according to the authors who have described them, are all endomorphic variations of diverse eruptive rocks of normal composition. This fact is entirely in harmony with the explanation given above concerning the origin of this rock. If it should be demonstrated later that the cordierite noryte was derived from an unmetamorphosed magma, it would then be necessary to admit the existence of a new magmatic type, whose existence from present data does not seem probable.

The silicoferrolyte (Fig. 1) is a type of exceptional characters. The most marked feature is the enormous development of the iron ordinate, but the excess of alumina is a very unusual occurrence, which indicates the existence of an aluminous spinel in the rock. The alkaline-earth triangle is so reduced as to be practically absent, and in fact the rock contains no feldspar. The amount of fayalite cannot be determined accurately from the per cent of silica since free quartz exists in the rock. Lang would class this type with the preceding in spite of its many peculiarities. It belongs to Brögger's melanokrate series, and to Michel Lévy's albitic magma, which is a subdivision of his ferromagnesian. Rosenbusch would consider it as derived from the peridotyte magma (π.) since the free quartz is wholly anomalous.

It will be noticed that AZ and MAZ of the silicoferrolyte are extremely low, and do not fall anywhere nearly within the limits considered characteristic of peridotyte magmas by Rosenbusch. This fact is in harmony with the theory that the silicoferrolyte is not a rock of purely igneous origin. However, very little importance is to be attached to this fact since Roth* has shown that these numbers AZ and MAZ possess no important significance.

Passing now to the method recently proposed by Brögger, which is a modification of that of Michel Lévy, it will be seen

*J. Roth· Die Eintheilung und die chemische Beschaffenheit der Eruptivgesteine: Zeitsch. d. d. Geol. Gesellsch. 1891. p. 41.

that, although certain of the principal advantages of the latter are lost in the modified diagrams, this method has certain advantages peculiar to itself. (See plate XIV.) Brögger prefers to use the relative number of molecules of each oxide instead of the relative weights, as used by Michel Lévy. The value of SiO_2 is carried on the horizontal axis, half in each direction from the center. The CaO is represented on the positive and the Al_2O_3 on the negative vertical axis. Two other axes are added, making angles of 30° with the horizontal, and on these the Na_2O is represented to the left below, the MgO to the right above, and the FeO to the left above. To the last is added the Fe_2O_3.

In the plate XIV, figure 3 represents the average of the olivine gabbro (1136) diabase (954) and olivine diabase (1843). The figure indicates the practical absence of potash, low sodium oxide, and rather high calcium oxide, about equaled by the magnesia, and the sum of the oxides of iron. The high per cent of calcium oxide and of alumina, and very low per cent of magnesia, iron and potash of the plagioclasyte (Fig. 2) appear very clearly. The extreme abundance of the iron is the feature of the silicoferrolyte (Fig. 4). The high per cent of magnesia and iron oxides is the distinguishing point in the troctolyte (Fig. 6). The alumina of the cordierite noryte (Fig. 5) is high in proportion to the calcium oxide, but the excess does not appear. A careful examination shows the increase of potassium oxide in the orthoclase gabbro (1797) (Fig. 7). Similarly a careful examination is necessary to detect the increase of silica in the quartz gabbro (854G) (Fig. 3.)

If now the point of view be changed, and the series be considered with Becke from the basal standpoint of the relation K : Na : Ca, it will be found that the chief features of the various types are largely lost to view. Indeed, this relation between the alkaline-earth metals is the only one conspicuously kept in view in the diagrams of Becke. (See plate XVI.) Becke considers two rectangular axes on which he lays off Na $= + 1$ on the x axis, and K $= + 1$ on the y axis. Then, for any given analysis, the co-ordinates n and k locate a point which is considered characteristic for the analysis. These coordinates are obtained from the relations:

$$n = \frac{Na - Ca}{Ca+Na+K}, \quad k = \frac{K - Ca.}{Ca+Na+K},$$

from which the co-ordinates of Ca can be found readily to be —1. The area between these three points Na, K, and Ca (called the horizontal field) is then divided by the rectangular axes and by a perpendicular from Ca upon KNa into six triangles, the coordinates of the included points of which correspond to the six possible unequal relations between K, Na, and Ca. To represent the other four elements of an analysis he lays off the values Si, Al, Mg, and Fe, using the metals always, on perpendiculars (to the plane of the paper) erected upon the point determined by the coordinates $n : k$, for the given analysis. These values are then projected upon a plane, called the vertical field, likewise perpendicular to the plane of the paper, and containing the median line CaA of the triangle. To obtain the abscissa for any rock, the foot A of the line CaA being considered zero, and the length CaA, unity, the relation used is (if a = abscissa required):

$$a = \frac{1}{\text{square root of } 2} \cdot \frac{\mathrm{Ca}}{\mathrm{Ca+Na+K}}$$

But a simpler method is to construct the horizontal field, as shown in plate XVI, with CaA horizontal, and project the points directly.*

It is seen from the horizontal field that the olivine gabbro (1136), the silicoferrolyte, (960), and the troctolyte (514), have practically identical proportions of the metals Ca, Na and K, while for the diabase (954), olivine diabase (1843), and plagioclasyte (336E), the proportions vary only slightly from each other, and from the first three. The orthoclase gabbro (1797), differs notably, containing relatively more K and Na, but it still remains in the triangle characterized by Ca > Na > K. On the contrary the quartz gabbro (854G) and cordierite noryte (983), are found in the triangle having Na > Ca > K, the only notable difference being that the noryte has relatively more K. In the vertical field it is seen that as the sodium and potassium relatively increase, the silica, in general, also increases; the other elements are conspicuously irregular, but in general decrease as the silica increases. Iron shows the greatest range varying from zero to a maximum exceeding the

*In the plate the central half only of the line CaA is represented as magnified to twice the original length.

highest silica of the series; aluminum is relatively constant near twenty per cent, with a maximum of thirty and a minimum of ten per cent. Magnesia is the lowest element, only twice exceeding ten per cent, and then only attaining twelve and fifteen per cent.

Iddings was the first to propose a graphic representation of rock composition, and his method is remarkably well adapted for the purpose for which it was devised, namely, to illustrate the consanguinity in certain series. His primary arrangement of the rocks is based on their relative acidity as given by the total per cent of SiO_2. The silica of each type is laid off as an abscissa, and from the points thus determined the various oxides are measured as ordinates; the alkalies and alumina in one diagram and the calcium, iron and magnesium oxides on another. The method thus has the marked advantage over the Becke diagrams of being incomparably more simple; neither one, however, is well adapted to illustrate a single rock.

In the plate (see plate XV), the original simplicity of the diagrams has perhaps been somewhat masked by the addition of several features.* Thus, to the diagram of the alkalies and alumina have been added the feldspathisable calcium oxide and the silica of the feldspars, while in two cases the alumina has been divided to indicate the presence of an excess. To the diagram of the ferromagnesian elements have been added the silica of those elements, and the excess of calcium oxide, occasionally replaced by the excess of alumina which is laid off in the negative direction.

Examining the upper diagram, the most striking feature is the quite constant proportion between *k*, *n* and *c* in the plagioclasyte, the olivine diabase, olivine gabbro, the diabase, the troctolyte, and the silicoferrolyte, and the variations in the three other rocks, (dotted lines). In four of these six types the proportion is almost exactly 1 : 5 : 15. In the olivine diabase this becomes 1 : 4 : 9; and in the plagioclasyte it is 1 : 9 : 25. Omitting the potassium the ratio is nearly 1 : 3 in all the types except the olivine diabase, where it is 1 : 2.3.

*Most of these modifications are as used by Michel Lévy. op. cit. p. 363, and plate XVI.

Therefore, the first six rocks are wholly comparable, showing only minor differences; from these the other three all differ markedly, while among themselves the orthoclase gabbro and cordierite noryte are comparable especially if the potash be disregarded, while the quartz gabbro stands alone. These differences and irregularities are well shown in the plate. In the lower figure the characteristics of the silicoferrolyte are strikingly evident: enormous per cent of iron; silica high for so basic a rock on account of the presence of free quartz; low magnesia, and a notable excess of alumina.

The various ratios are conspicuously variable. In both figures the plagioclasyte is a marked rock with its high alumina and calcium oxide, and practical absence of all ferromagnesian elements. The cordierite noryte is also conspicuous by its relatively low content of feldspathic constituents, high ferromagnesian silica and extraordinary excess of alumina.

In conclusion, it is seen that the comparison of these various methods of graphic representation shows that the method of Iddings, while excellent for its purpose, is not at all suited for a single rock analysis, nor well adapted to general use. The method of Becke gives too much prominence to the relation K:Na:Ca, which is not characteristic for the alkaline-earth constituents, except when no excess of CaO exists. It is too complicated for general use, and many important relations are not brought out conspicuously.

The object of Brögger is simplicity, but the choice of the relative number of molecules (quotientzahl) introduces an unnecessary complication, since the relations of the relative weights are fully as characteristic. He avoided the assumption of Michel Lévy that all the alumina is contained in the feldspars, which is admittedly only an approximation, but in avoiding this Brögger loses some of the important advantages of the method of Michel Lévy. The latter method then is evidently the best hitherto devised, for a single analysis, as well as for general use. Its weak point, of course, is the assumption just mentioned, but this loses its importance if it is remembered that it is not supposed to be necessarily an expression of fact, but only a possibility the verification of which is to be accomplished by the mineralogical study.

The method of Michel Lévy presents at a glance a clear conception of the whole chemical character of the rock with indications, nearly always quite precise, as to the mineralogical composition. It permits a ready reconstruction of the full chemical composition* of the rock from the diagram itself. One of its important points of superiority is the clearness with which the various ratios between the oxides appear. It separates the feldspathisable calcium oxide from that entering into the ferromagnesian minerals, and if an excess of either alumina or sodium oxide occurs it is brought out with remarkable clearness.

(*Concluded.*)

METEOROLOGY OF THE ORDOVICIAN.

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Meteorologic conditions in the Ordovician time are to be considered apparently as nearly indeterminable because of insufficiency and indirectness of evidence. One may of course say that the Ordovician had pre-Carboniferous climatic conditions, or even that the Ordovician is to the Carboniferous as the Carboniferous is to Recent climate, which however, means nothing definite if we are not agreed on the Carboniferous conditions. In such a state of knowledge upon an important subject, any direct evidence, however slight may be welcomed in printed form, and therefore the following is offered.

What may be considered as direct evidence on the subject is found in a fossil of the Monticuliporoidea which occurs in the Ordovician, and which winds at least simulating heliotropism. Rhinidictya mutabilis *Ulr.*, is found fossil as more or less broken parts of a zoarium which when reconstructed may be described as follows: It grew attached to the sea bottom by a small basal expansion from the center of which rose a dichotomously branching calcareous skeleton to the hight of 100 mm or less. The growth was at the branch ends mainly, the branches thickening very slowly below these points. The whole zoarium resembles a sea weed in habit, although in fact

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*With the exception, of course, of such elements as TiO_2, P_2O_5 H_2O, CO_2, etc.

built by a colony of zooids or polypites. The zoarial stem and branches are nearly flat, becoming lens-shape in transverse section with age. They are made up of closely amalgamated tubes or cells which begin blindly at the medial part and open upon either surface of the zoarium, each being the work or skeleton of a zooid, the whole zoarium being the skeleton of a colony of zooids. The structure of the zoarium bears, in general, evidence of having been built by a closely incorporated colony, much like the gorgonids among corals.

What is remarkable further is that the branches twist as they ascend and turn the faces of the zoarium thus from east to west. This could be explained as due to influence of the sun's rays upon the zooids, those that were in the most favorable position growing a little the faster and crowding their neighbors, and the crowding following the sun's course caused a twisting from east to west. A tendency to turn in that direction would become finally inherent. This turning might be explained also as a device to prevent the repeatedly dividing branches from interfering, but it appears to be not defined by that use since the twisting is least marked where the branching is most frequent as in the lower older part of the

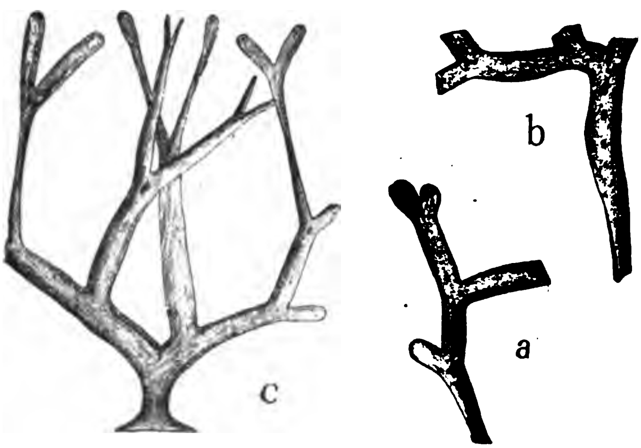

Figure 1.

Explan. Fig. 1. Rhinidictya mutabilis *Ulrich*, from the Ordovician Trenton strata at Saint Paul, Minnesota. a) Part of a zoarium showing branches twisting from left to right. b) Similar piece with vertical branch twisted and horizontal branch not twisted. c) A small specimen partly restored.

zoarium. And moreover the important fact remains that they twist from left to right.

Rhinidictya species have very strongly acrogene narrow flattened branches as compared to other monticuliporoids, and they are thus the ones most suited to show the twisting as well as to have become heliotropic. A similar species, Pachydictya acuta *Hall*, associated with it, is somewhat less acrogene and is less twisted. Other related forms in which this phenomenon does not appear, evince some reasons therefor, but which need not be enumerated. Pachydictya firma Ulr., occurring in a higher stratum of the Ordovician has a twisted broad stalk, which is, however, the narrowest part of the zoarium. In this species the turning is from right to left, the reverse of P. acuta *Ulr.*, and Rhinidictya.

No mention of heliotropism or regular turning of any kind is made in the original descriptions of the species, except in P. firma which is said to be "usually twisted compressed branches," but original figures represent it clearly in Rhinidictya mütabilis.* The species may already be generally known by name, or even by their characters other than those here specially mentioned.

The geologic conditions are such as to indicate that the species lived in shallow water not far from shore. Rhinidictya mutabilis *Ulr.* and Pachydictya acuta *Ulr.* occur most abundantly at Saint Paul, Minnesota, but also in neighboring counties and in Wisconsin and Iowa in part. They are from the so-called Trenton here which is equivalent in time to the lower part of the Trenton stage in New York. At that time there is supposed to have been a shallow sea or bay between Minnesota peninsula † and Isle Wisconsin. Saint Paul is evidently near the site of the old shore. This locality is now at 45 degrees north latitude. The evidence afforded by the fossils suggests that then the earth rotated and the sun shone as now.

The Pachydictya firma *Ulr.*, occurs at Wilmington, Illinois, near 41 degrees north, in the uppermost of the Cincinnati shales, and its exceptional turning from right to left,

*Geol. Nat. Hist. Survey Minn., Final Rep., v. 3, p. 125, pl. 7.

†See Geol. Wis. v. I, p. 15, and map.

need not be thought of as proving that locality to have been southward from the then equatorial line. Rather the turning is strongest in the early zoarial growth and later becomes confused irregularly, suggesting that the character is only a hereditary one; and that the species possessing it may have then recently immigrated from south of the equator.

EDITORIAL COMMENT.

TROOST'S MAP OF THE ENVIRONS OF PHILADELPHIA.

In Marcou's Mapoteca Geologica Americana (Bulletin No. 7. U. S. Geological Survey 1884), on page 64, is given the following:

> 1826—Troost (Gerard). Karte der Gegend von Philadelphia. Accompanying "Geological survey of the environs of Philadelphia," cited by C. Cotta, in his "Geognostische Karten unseres Jahrhundert's 1850, p. 48, No. 533. This map is unknown even in Philadelphia, and contemporaries of Troost, such as the late T. Conrad, and Mr. Isaac Lea, had never heard of such a map. It is very doubtful if it exists.

In view of the above statement it may be worth while to call attention to the fact that a map of the above area was published in 1826 and issued in a pamphlet of 40 pages, entitled, Geological | Survey | of the | Environs of Philadelphia; | Performed by order of the | Philadelphia Society for promoting Agriculture. | By | G. Troost, M. D. | Philadelphia: | Published by H. S. Tanner, 177 Chestnut Street. | Clark & Raser, Printers, 34 Carter's Alley. | 1826. |

The map itself is some ten by fourteen inches, and comprises that part of Pennsylvania forming a semicircle or segment of a circle, "whereof the center is the rotunda in High street, Philadelphia, and the radii extend 15 miles, bounded on the east by the River Delaware." The rocks are all classed as primordial, and as colored on the map the area as far north as Chestnut hill and a little beyond belongs to the gneiss formation, beyond this being narrow belts of, first, primitive clay-slate, and second, limestone, with a small area of serpentine interpolated between the gneiss

and the clay-slate; of euryte between the clay-slate and limestone; and a narrow belt of transition in the extreme northeast portion. "The gneiss," he says "which contains here and there some subordinate formations, runs in a direction generally from northeast to southwest. The subordinate formations of this gneiss are the diabase (1) and the pegmatite (2), in which sometimes the feldspar occurs of an earthy appearance or kaolin (3), being abundantly intersected by veins or, properly speaking, strata or eurite (4)." The "Talcose or serpentine formation" occurring near Chestnut hill is described as of a dark green approaching to black color, and in it he finds the "steatitose steaschiste" which is used in Philadelphia under the name of soapstone.

The rock which is colored on the map as euryte he describes as being equivalent to the weistein of Werner, and he naively remarks: "I am much delighted at meeting this rock for the first time this side of the Atlantic. I imagined myself transported to the Erzgebirge in Saxony, and remembered with renewed pleasure the father of geology who made us acquainted with it."

The mineralogical character of the rocks is described in considerable detail in the first fourteen pages of the pamphlet, the remainder being given up to a description of the soils and their physical and chemical composition. The work is naturally of purely historical interest, but in view of the statment of Marcou as quoted above, seems worthy of note here. G. P. M.

REVIEW OF RECENT ·GEOLOGICAL LITERATURE.

Scapolite Rocks from Alaska; by J. E. SPURR. (Am. J. Sci., *160*-310-315).

The first rock described is an andesine-oligoclase-scapolite-biotite rock of granitoid texture, occurring in the form of great dikes cutting through an older igneous rock—granite and dioryte. The scapolite is considered the equivalent of a feldspar in the rock and the latter is placed parallel to the belugyte group of 'feldspar rocks as a scapolite belugyte. The name yentnyte is suggested and the type becomes a biotite yentnyte. A local variation of this rock is described as microcline scapolitic. The second rock, a light colored dike rock cutting Cretaceous shales and limestones, is described as a quartz-scapolite porphyry and is placed parallel to the quartz monzonyte group of feldspar rocks. It is given the name of kuskyte. The author is of the opinion that the gasses—chlorine, etc.—played an important part in the formation of the scapolite; but he considers the latter to be undoubtedly an original constituent and not of secondary origin as is probably the case with the Norwegian scapolite rocks. C. H. W.

Graftonite, a New Mineral from Grafton, N. H., and its Intergrowth with Triphylite; by S. L. PENFIELD. (Am. J. Sci., *160*-20-32).

The new mineral occurrs in a coarsely crystalline pegmatitic vein of quartz and feldspar. Its composition as shown by chemical analysis is represented by the formula $R''_3P_2O_8$, where R'' represents the isomorphus elements iron, manganese and calcium in varying proportions. This places it in the rare group of anhydrous, normal phosphates of which triphylite is also a member. The latter occurs in thin, dark layers distinctly interlaminated with the light colored graftonite. Microscopical examination brings out the interesting fact that the two minerals have a definite crystallographic orientation with respect to each other. Apparantly, graftonite, which constitutes something over two-thirds of the whole mass, was in sufficient quantity to give its own monoclinic symmety to the crystals and at the same time by reason of some similarity of molecular structure, has caused the laminæ of the orthorhombic triphylite to take a definite crystallographic orientation. These relations and the crystal habit are shown by appropriate drawings. C. H. W.

Two New Occurrences of Corundum in North Carolina; by J. H. PRATT. (Am. J. Sci., *160*-295-298).

The first occurrence is in an amphibole schist apparently a metamorphosed igneous rock of the gabbro type. The corundum is found in seams a few feet in width, and forms about 10 per cent of the vein. The second is in a quartz schist, composed of biotite mica and quartz in which the corundum is found along streaks or bands. It is thought that the excess of alumina contained in the original shales, which were afterwards metamorphosed into quartz schist, crystallized out along the planes of lamination. C. H. W.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Becker, G. F.

Brief memorandum on the geology of the Philippine islands. (20th Ann. Rep., U. S. Geol. Sur., Part 2, pp. 1-7.)

Bishop, Irving P.

Petroleum and natural gas in western New York. (51st report N. Y. State Mus., vol. 2, pp. 10-62, Albany, 1899.)

Branner, J. C.

The oil-bearing shales of the coast of Brazil. (Am. Int. Min. Eng., Aug., 1900.)

Brooks, A. H.

A reconnoissance in the White and Tanana river basins, Alaska, in 1898. (20th Ann. Rep., U. S. G. S., Part 7, pp. 425-494, pls. 36-38.)

Chamberlin, T. C.

Proposed international geological institute. (Jour. Geol., vol. 8, pp. 596-609, Oct.-Nov. 1900.)

Crosby, W. O.

Geology of the Boston basin, vol. 1, part 3. The Blue Hills complex. (Occasional Papers of the Boston Society of Natural History, IV, pp. 289-600, two maps, pls. 15-30, 1900.)

Dale, T. Nelson.

A study of Bird mountain, Vermont. (20th Ann. Rep., U. S. G. S., Part 2, pp. 9-24, pls. 1-24.

Diller, J. S.

The Bohemia mining region of western Oregon. (20th Ann. Rep., U. S. G. S., 1898-99, Part 3, pp. 1-36.)

Eldridge, Geo. H.

A reconnoissance in the Sushitna basin and adjacent territory, Alaska. (20th Ann. Rep., U. S. Geol. Sur., Part 7, pp. 1-29. pls. 1-6.)

Emmons, S. F.

Map of Alaska with descriptive text. U. S. Geol. Sur., 1898.

Geikie, Archibald.

De la coopération internationale dans les investigations géologiques. (Jour. Geol., vol. 8, pp. 585-595, Oct.-Nov. 1900.)

Gidley, J. W.

A new species of Pleistocene horse from the Staked Plains of Texas. (Bull. Am. Mus. Nat. Hist., vol. XIII, pp. 111-116, Aug. 1900.

Girty, G. H.

Devonian fossils from southwestern Colorado; the fauna of the Ouray limestone. (20th Ann. Rep., U. S. G. S., Part 2, pp. 25-81, pls, 3-7.)

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology, and mineralogy.

Grabau, A. W.

Paleontology of the Cambrian terranes of the Boston basin. (Occasional Papers of the Boston Society of Natural History. IV. pp. 601-694, pls. 31-39, 1900.)

Hamilton, S. Harbert (and James R. Withrow.)

The progress of Mineralogy in 1899. Bull. No. 2. Am. Inst. Min. Eng., 1900.

Hovey, E. O.

The geological and paleontological collections in the American Museum of Natural History. (Science, vol. 12, pp. 757-760. Nov. 16, 1900.)

Hovey, E. O. (R. P. Whitfield and)

Catalogue of the types and figured specimens in the paleontological collection of the geological department, American Museum of Natural History. (Bull. Am. Mus. Nat. Hist., vol 11, pp. 189-356, Oct. 12, 1900.)

Kemp, J. F. (and D. H. Newland.)

Preliminary report on the Geology of Washington, Warren and parts of Essex and Hamilton counties. (51st report N. Y. State Mus., vol. 2 pp. 399-553, 1809.

Knight, W. C.

A preliminary report on the Artesian basins of Wyoming. Bull. No. 45, Wyo. Exper. Sta. pp. 105-251, plates, June, 1900.

Knowlton, F. H.

Fossil plants associated with the lavas of the Cascade range. (20th Ann. Rep., U. S. Geol. Sur. Part 3, pp. 34-52, pls. 1-6.)

Lee, W. T.

The glacier of Mt. Arapahoe, Colorado. (Jour. Geol., vol. 8, pp. 647-654, Oct.-Nov., 1900.

Lindgren, Waldemar.

The gold and silver veins of Silver City, De Lamar and other mining districts in Idaho. (20th Ann. Rep., U. S. G. S., Part 3, pp. 65-256, pls. 7-35.)

Mendenhall, W. C.

A reconnoissance from Resurrection bay to the Tanana River, Alaska. (20th Ann. Rep., U. S. G. S., Part 7, pp. 266-340, pls. 14-21.)

Ortman, A. E.

Synopsis of the collections of invertebrate fossils made by the Princeton expedition to southern Patagonia. (Am. Jour. Sci., vol. 10, pp, 368-381, Oct., 1900.)

Osborn, H. F.

Reconsideration of the evidence for a common Dinosaur -Avian stem in the Permian. (Am. Nat., vol. 34, pp. 777-779, Oct. 1900.)

Parks, W. A.

The Huronian of the Moose River basin. (Univ. Tor. Studies, Geol. series No. 1, 35 pp.,1900.)

Penck, Albert.

The Illecillewaet glacier in the Selkirks. (Proc. Can. Inst., vol. ? Read Apr. 29, 1899.)

Penck, Albert.

Observations made on a Tour in Canada. (Proc. Can. Inst., vol. ?, Read March 16, 1898.)

Penfield, S. L.

Chemical composition of turquois. (Am. Jour. Sci., vol. 10, pp. 346-350, Oct., 1900.)

Pirsson, L. V.

Petrography of the igneous rocks of the Little Belt Mountains. (20th Ann. Rep., U. S. G. S., Part 3, pp. 463-581, pls. 70 to 77.)

Prosser, C. S.

Classification and distribution of the Hamilton and Chemung series of central and eastern New York. Part 2. (51st report, N. Y. State Mus., vol. 2, pp. 65-327, 1899.

Prosser, C. S. (and R. B. Rowe.)

Stratigraphic geology of the eastern Helderbergs. (51st report N. Y. State Mus., vol. 2, pp. 331-354, 1899.)

Prosser, C. S.

The Shenandoah limestone and Martinburg shale. (Jour. Geol., vol. 8, pp. 655.663, Oct.-Nov., 1900.)

Ries, Heinrich.

Limestones of New York and their economic value. (51st report N. Y. State Mus., vol. 2, pp. 355-467. 1899.

Ries, H.

Clays and shales of Michigan, their properties and uses. (Vol. 7, Geol. Sur. Mich., pp. 1-67, 4 pls. 1900.)

Rowe, R. B. (C. S. Prosser and)

Stratigraphic geology of the eastern Helderbergs. (51st report N. Y. State Mus., vol. 2, pp. 331-354, 1899.)

Russell, I. C.

A preliminary paper on the Geology of the Cascade mountains in Washington. (20th Ann. Rep. U. S. G. S., Part 7, pp. 83-210, pls. 8-20.)

Schrader, F. C.

A reconnoissance of a part of Prince William Sound and the Copper River District, Alaska, in 1898. (20th Ann. Rep., U. S. G. S., Part 7, pp. 341-423. pls. 22-35.

Smith, W. S. Tangier.

A topographic study of the islands of southern California. (Bull. Dept. Geol., Univ. Cal., vol. 2. pp. 179-230. Sept., 1900.)

Smyth, C. H., Jr.

Report on the crystalline rocks of the western Adirondack regions. (51st report N. Y. State Mus. vol. 2, pp, 469-497.)

Sollas, W. J.

Evolutional Geology. (Science, vol. 12, pp. 725-756, Nov. 16, 1900.)

Spurr, J. E.

A reconnoissance in southwestern Alaska in 1888. (20th Ann. Rep., U. S. G. S., Part 7, pp. 31-264, pls. 7-13.)

Spurr, J. E.

Quartz muscovite rock from Belmont, Nevada; the equivalent of the Russian beresite. (Am. Jour. Sci., vol. 10, pp. 351-356. Oct. 1900.)

Spurr, J. E.

Succession and relation of lavas in the great basin region (Jour. Geol., vol. 8, pp. 621-646, Oct.-Nov., 1900.)

Tillman, S. E.

A text-book of important minerals and rocks, with tables for the determination of minerals. pp. 176. John Wiley and Sons, New York, 1900.

Todd, J. E.

Geology and water resources of a portion of southeastern South Dakota, (U. S. Geol. Sur., Water-Supply and Irrigation papers No. 34, pp. 34, 1900.)

Ward, L. F.

Status of the Mesozoic floras of the United States. (20th Ann. Rep., U. S. G. S., Part 1, pp. 211-747, pls. 21-179.)

Ward, L. F.

Elaboration of the fossil Cycads in the Yale museum. (Am. Jour. Sci.,.vol. 10, pp. 327-345, Nov., 1900.)

Washington, H. S.

The composition of kulaite. (Jour. Geol., vol. 8, pp. 610-620. Oct.-Nov., 1900.)

Weed, W. H.

Geology of the Little Belt mountains, Montana. (20th Ann. Rep., U. S. G. S., Part 3, pp. 257-461, pls. 36-69.)

Whitfield, R. P. (and E. O. Hovey.)

Catalogue of the types and figured specimens in the paleontological collection of the geological department, American Museum of Natural History. (Bull. Am. Mus. Nat. Hist., vol. 11, pp. 189-356, Oct. 12, 1900.)

Withrow, James R. (S. H. Hamilton and)

The Progress of Mineralogy in 1899.) Bull. No. 2. Am. Inst. Min. Eng. 1900)

PERSONAL AND SCIENTIFIC NEWS.

Prof. A. G. Leonard of the University of Missouri has been appointed to the chair of mining and mineralogy at the University of Idaho at Moscow.

Prof. George H. Barton will give a course of twelve lectures, in the Lowell Institute series, on Geology in its relation to Topography, and its bearing upon the work of engineers.

Thomas Benton Marbut died suddenly at Esther, Missouri, on Sunday, Sept. 16, 1900. Mr. Marbut was one of the

younger geologists who had already accomplished considerable scientific work of high merit. His efforts along the lines of investigation in which he was engaged portended a most promising career. He was for several years engaged upon the Missouri geological survey and upon the United States geological survey. At the time of his demise he was occupied in carrying out certain lines of geological work for private corporations.

Mr. Marbut was born in 1871. After passing through the common schools he was engaged in teaching in the public schools of southern Missouri. He was a graduate of the Missouri state university, and was valedictorian of his class.

From 1891 to 1897 Mr. Marbut was more or less continuously connected with the Missouri geological survey. As assistant topographer he was largely instrumental in constructing the beautiful topographic bases of the Clinton, Calhoun and other sheets published by the Missouri geological survey. During the season of 1897 he was given charge of the work of collecting data in regard to the coal deposits of north Missouri, the results of which were to be published as a part of the final report on the coal resources and coal geology of the state, that was planned and well along in preparation, by Dr. Charles R. Keyes. The summer of 1897 was spent by Mr. Marbut in topographic mapping for the United States geological survey.

As Mr. Marbut's main work was in economic geology and largely undertaken for private corporations, few of his results have yet found their way into print. In 1898 he was engaged in mapping topographically and geologically the properties of the celebrated Liberty Bell Gold Mining company, at Telluride, Colorado. When this was completed he was appointed engineer for the same company, having charge of the properties at both Telluride and Joplin, Mo. For the Liberty Bell company Mr. Marbut made an elaborate investigation of the lead deposits of southeast Missouri and especially those of the St. Francois district.

In January, 1900, Mr. Marbut accepted the appointment of engineer and assistant superintendent of the Columbia Lead company, with headquarters at Esther, Mo., where the mines of this company are located. This post he held at the time of his death.

Personally, Mr. Marbut was frank, generous, and of pleasing disposition. By his modest demeanor, his quiet enthusiasm for his work, and his strict attention to duty at all times, he soon won for himself the highest regards of his associates. His sterling qualities and indefatigable effort enabled him to accomplish whatever he once set out to do. His intellectual attainments were of a high order.

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INDEX TO VOL. XXVI.

JULY, 1900. VOL. XXVI, No. 1

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The "List of Recent Publications," will be continued as an AUTHOR'S CATALOGUE, arranged alphabetically for each month. In this catalogue will be included only American publications so far as they come to our knowledge, and it will embrace substantially, all current American geological literature. Such catalogue will be a fair exponent of the activity of American geologists in general and physiographic geology, paleontology, petrography and mineralogy. It will appear each month, and will note articles received up to the 20th of the preceding month. It will be of much value to working geologists, and to librarians.

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